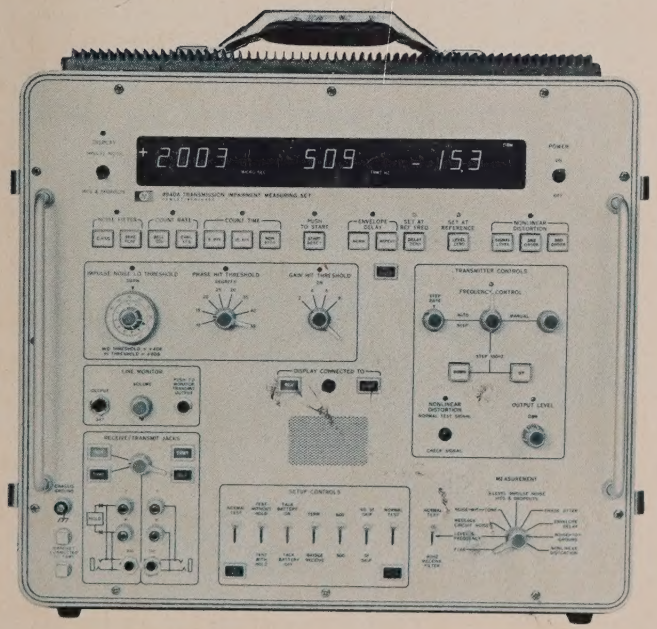
OPERATING MANUAL

4940A

TRANSMISSION IMPAIRMENT MEASURING SET



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CERTIFICATION

Hewlett-Packard Company certifies that this instrument met its published specifications at the time of shipment from the factory. Hewlett-Packard Company further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY AND ASSISTANCE

This Hewlett-Packard product is warranted against defects in materials and workmanship for a period of one year from the date of shipment. Hewlett-Packard will, at its option, repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard, and provided the preventive maintenance procedures in this manual are followed. Repairs necessitated by misuse of the product are not covered by this warranty. NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. HEWLETT-PACKARD IS NOT LIABLE FOR CONSEQUENTIAL DAMAGES.

Service contracts or customer assistance agreements are available for Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

HEWLETT hp PACKARD

OPERATING MANUAL

4940A

TRANSMISSION IMPAIRMENT MEASURING SET

All Serial Numbers

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04940-90010

5070 Centennial Blvd., Colorado Springs, CO 80919

PRINTED: JANUARY 1982

WARNING

SAFETY

If this instrument is to be energized via an autotransformer for voltage reduction, make sure the common terminal is connected to the earthed pole of the power source.

BEFORE SWITCHING ON THIS INSTRUMENT, the protective earth terminals of this instrument must be connected to the protective conductor of the (mains) power cord. The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. The protective action must not be negated by use of an extension cord (power cable) without a protective conductor (grounding).

Make sure that only fuses with the required rated current and of the specified type (normal blow, time delay, etc.) are used for replacement. The use of repaired fuses and the short-circuiting of fuse holders must be avoided.

Whenever it is likely that the protection offered by fuses has been impaired, the instrument must be made inoperative and be secured against any unintended operation.

GROUNDING

Any interruption of the protective (grounding) conductor (inside or outside the instrument) or disconnecting the protective earth terminal can make this instrument dangerous. Intentional interruption is prohibited.

HIGH VOLTAGE

Any adjustment, maintenance, and repair of the opened instrument under voltage should be avoided as much as possible and, when inevitable, should be carried out only by a skilled person who is aware of the hazard involved.

Capacitors inside the instrument may still be charged even if the instrument has been disconnected from its source of supply.

Adjustments and service described herein are performed with power supplied to the instrument while protective covers are removed. Energy available at many points, if contacted, result in personal injury.

CAUTION

LINE VOLTAGE

BEFORE SWITCHING ON THIS INSTRUMENT, make sure instrument requirements match the voltage of the power source.

GROUNDING

BEFORE SWITCHING ON THIS INSTRUMENT, ensure that all devices connected to this instrument are connected to the protective (earth) ground.

BEFORE SWITCHING ON THIS INSTRUMENT, ensure that the line power (mains) plug is connected to a three-conductor line power outlet that has a protective (earth) ground. (Grounding one conductor of a two-conductor outlet is not sufficient.)

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Figure 1-1. Hewlett-Packard 4940A Transmission Impairment Measuring Set

GENERAL INFORMATION

SECTION I

1-1. INTRODUCTION.

1-2. This manual contains the information required to install and operate the Hewlett-Packard Model 4940A Transmission Impairment Measuring Set (TIMS). This section covers a general description, identification, specifications, options, accessories, related manuals, and other basic information. Figure 1-1 shows the test set with its cover removed.

1-3. The various sections in this manual provide information as follows:

a. SECTION II, INSTALLATION. Provides information relative to unpacking and inspection, power requirements, mounting, checkout, packing and shipping, etc.

b. SECTION III, OPERATION. Provides information relative to operating controls and indicators and the operating instructions for the test set.

c. SECTION IV, MEASUREMENT PRINCIPLES. Provides functional description of all measurements.

1-4. GENERAL DESCRIPTION.

1-5. TIMS is a multifunction test set which measures the data handling capability of a voice communications channel. The voice channel parameters which TIMS measures are (1) loss, (2) dropouts, (3) gain hits, (4) phase hits, (5) phase jitter, (6) noise-with-tone, (7) noise-to-ground, (8) frequency shift, (9) nonlinear distortion, (10) message circuit noise, (11) 3-level impulse noise, (12) attenuation distortion, (13) envelope delay distortion, (14) peak-to-average ratio (P/AR), and (15) single frequency interference. TIMS also includes a comprehensive self-check capability.

1-6. IDENTIFICATION.

1-7. Hewlett-Packard identification can be made by reviewing the identification plate on the bottom of the test set case (see figure 1-2). Hewlett-Packard products carry a model number, an option listing, and a ten-digit serial number. The model number corresponds to the placarding on the front panel and the option number(s) indicates those options which the customer has specified, if any.

1-8. Hewlett-Packard identifies each unit with a two-section serial number (0000A-00000). The first four digits are a serial number prefix used to identify a particular unit configuration. The letter code identifies the country in which the unit was manufactured (e.g., the letter "A" indicates manufactured in U.S.A.). The last five digits identify each specific unit. If the serial number prefix on the unit does not agree with the prefix on the title page of this manual, there are differences between that unit and the unit described in this manual. These differences are described in manual supplements available at the nearest HP Sales and Service Office or in Appendix A of this manual.

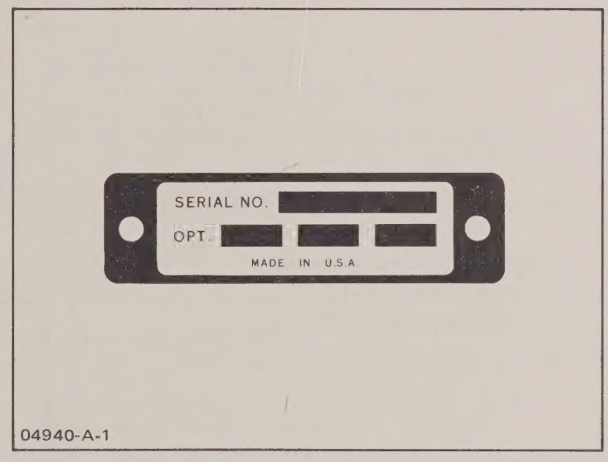


Figure 1-2. Identification Plate

1-9. SPECIFICATIONS.

1-10. Specifications for TIMS are listed in table 1-1.

1-11. OPTIONS.

1-12. Options are factory modifications of a standard TIMS that are requested by the customer. Available options are (1) Option 001 allowing P/AR measurement, (2) Option 002 allowing nonlinear distortion measurement, (3) Option 003 allowing both P/AR and nonlinear distortion measurement, (4) Option 019 allowing mounting in a 19 in. relay rack, and (5) Option 023 allowing mounting in a 23 in. relay rack.

1-13. ACCESSORIES.

1-14. Available as an accessory for the 4940A TIMS is the Model 18047A Fiberglass Transit Case (Option 010). This case is used to provide additional protection for the test set when it is shipped from location to location. This accessory may be ordered with TIMS or separately from your local Hewlett-Packard Sales and Service Office (refer to the list at the back of this manual for addresses).

1-15. RELATED MANUALS.

1-16. Summarized operating instructions for the test set are provided in the 4940A Operating Instructions booklet, HP P/N 04940-90014. Complete service information for the test set is provided in the 4940A Service Manual, HP P/N 04940-90012, which may be obtained by returning the card enclosed in this manual.

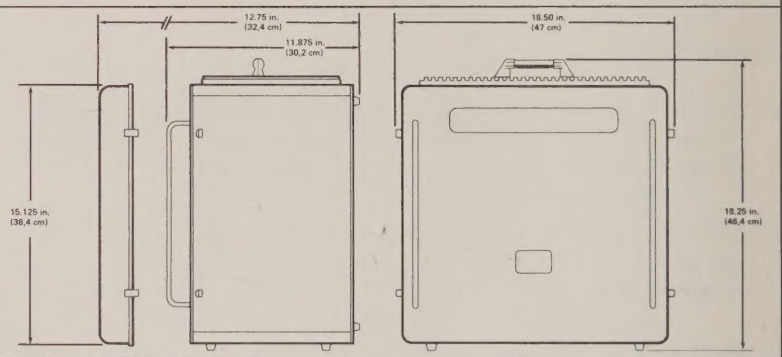
1-17. TIMS REPAIR.

1-18. User repairs should be limited to replacement of fuses, annuciator lamps, and power cords. Repairs and adjustments of electronic circuits should not be attempted. These repairs require special equipment and procedures and should be performed only by authorized repair shops. For any needed assistance contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

Table 1-1. HP 4940A TIMS Specifications

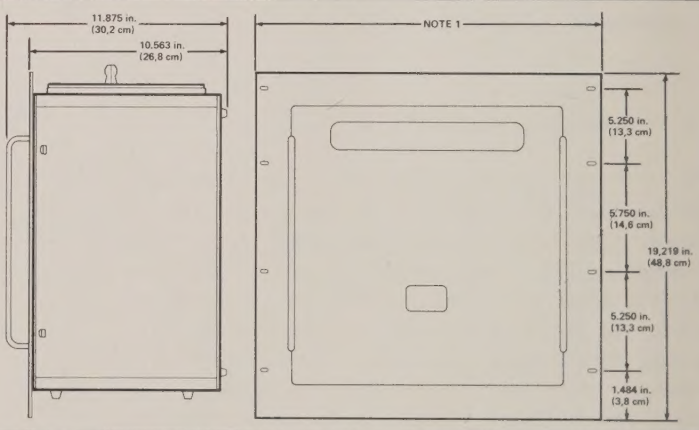
DIMENSIONS AND WEIGHTS

Standard Model
Net: 39 lbs. (18 kg)
Shipping: 50 lbs. (22,7 kg)



Rack Mount Option Models
Net: 40 lbs (18,1 kg)
Shipping: 50 lbs. (22,7 kg)

Note 1. Option 019: 19.00 in. (48,3 cm)
Option 023: 23.00 in. (58,4 cm)



Model 18047A Fiberglass Transit Case
Net: 18 lbs. (8 kg)

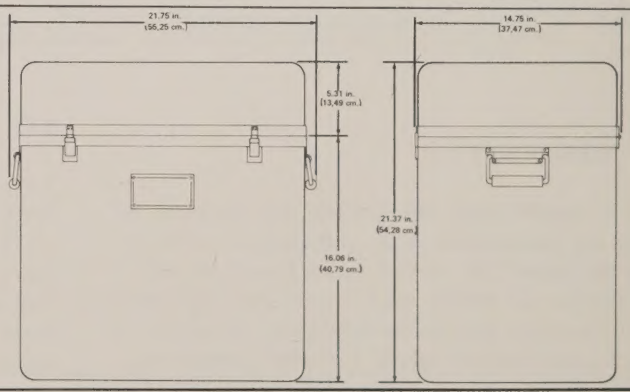


Table 1-1. HP 4940A TIMS Specifications (Continued)

TRANSMITTER	RECEIVER
LEVEL AND FREQUENCY Frequency Range: 200 Hz to 3904 Hz Resolution: 1 Hz Accuracy: ±0.5 Hz in Step Modes Manual Mode: Continuously adjustable; 200 Hz to 3900 Hz Step 100 Hz Mode: 204 Hz to 3904 Hz in 100 Hz increments Auto Step Mode: Repeatedly steps up and then back (in 100 Hz increments) from 204 Hz to 3904 Hz Level Range: +10 dBm to −40 dBm Resolution: 0.1 dBm Accuracy: ±0.1 dB Frequency Response: ±0.1 dB from 200 Hz to 3904 Hz Harmonic and Spurious Signals: Total Harmonic Distortion to 10 kHz: Greater than 50 dB below fundamental Spurious Signals to 10 kHz: Greater than 50 dB below fundamental Background Noise to 10 kHz: Less than −90 dBm	Frequency Range: 200 Hz to 4100 Hz Resolution: 1 Hz Accuracy: ±0.5 Hz Level Range: +10 dBm to −40 dBm Resolution: 0.1 dBm Accuracy: ±0.1 dB at 1 kHz from 0 to −15 dBm; ±0.2 dB over full frequency and level range Detector: Full wave average Bandwidth (3 dB points): Nominal 20 Hz to 10 kHz 60 Hz Input Filter (switch selectable): Nominal 25 dB loss at 60 Hz; 4 dB loss at 180 Hz
PHASE JITTER Frequency: 1004 Hz fixed Level Range: +10 dBm to −40 dBm Resolution: 1 dBm Background Noise, Harmonics and Spurious Signals: Refer to LEVEL AND FREQUENCY	Frequency Range: 990 Hz to 1030 Hz Level Range: +10 dBm to −40 dBm Resolution: 1 dBm Jitter Range: 0.2 to 25 degrees Resolution: 0.1 degree Accuracy: ±5% of reading ±0.2 degrees Detector: Peak to peak Bandwidth (3 dB points): Nominal 20 Hz to 300 Hz
MESSAGE CIRCUIT NOISE Quiet Termination	Weighting Filters: C-Message and 3 kHz flat Detector: Quasi RMS Range: +10 dBrn to +100 dBrn Resolution: 1 dBrn Accuracy: ±1 dB
3-LEVEL IMPULSE NOISE, HITS AND DROPOUTS Frequency: 1004 Hz fixed Level Range: +10 dBm to −40 dBm Resolution: 1 dBm Background Noise, Harmonics and Spurious Signals: Refer to LEVEL AND FREQUENCY	Received Tone Level: 0 dBm to −40 dBm Notch Filter: Greater than 50 dB rejection from 995 Hz to 1025 Hz Count Interval: 5 min., 15 min. or continuous Impulse Noise Threshold Range: Lo: 30 dBrn to 109 dBrn Mid: 4 dB above Lo (Max 109 dBrn) Hi: 8 dB above Lo (Max 109 dBrn) Impulse Noise Threshold Accuracy: ±1 dB Impulse Noise Count Range: Lo: 0 to 19,999 Mid: 0 to 9,999 Hi: 0 to 1,999 Count Rate: 7 counts per second max. ±5% or channel limited Gain Hit Thresholds: 2, 4, 6, and 8 dB Phase Hit Thresholds: 10 to 45 degrees in 5 degree increments Hit Guard Interval: Nominal 4 ms Dropout-Level Threshold: Fixed; greater than 12 dB decrease in level Dropout Duration: Nominal 4 ms (±10%) or greater Phase Hit Counts: 0 to 19,999 Dropout Counts: 0 to 9,999 Gain Hit Counts: 0 to 1,999 Display: All six phenomena are counted simultaneously and stored. A switch selection displays either the Impulse Noise counts or the Hits and Dropout counts during or after the measurement period.
NOISE-TO-GROUND Quiet Termination	Range: 40 dBrn to 130 dBrn Input Circuit: 600Ω or 900Ω across the line; 100 kΩ to ground For other specifications refer to MESSAGE CIRCUIT NOISE

Table 1-1. HP 4940A TIMS Specifications (Continued)

TRANSMITTER	RECEIVER
ENVELOPE DELAY Frequency Range: 300 Hz to 3904 Hz For other Frequency specifications see LEVEL AND FREQUENCY Modulation Frequency: 83⅓ Hz Level Range: +10 dBm to -40 dBm For other Level specifications see LEVEL AND FREQUENCY Harmonic and Spurious Signals to 10 kHz: Greater than 46 dB below main signal power. Background Noise to 10 kHz: Less than −90 dBm	Frequency Range: 300 Hz to 3904 Hz For other Frequency specifications see LEVEL AND FREQUENCY Level Range: +10 dBm to -40 dBm Carrier Level Accuracy: ±.25 dB For other Level specifications see LEVEL AND FREQUENCY Delay Range: −3,000μs to +9,000μs Resolution: 1μs Accuracy (back to back): ±10μs from 600 Hz to 3904 Hz; ±30μs from 300 Hz to 600 Hz Minimum Signal to Noise Ratio (for stated accuracy): 20 dB, 3 kHz flat weighting
NOISE-WITH-TONE Frequency: 1004 Hz fixed Level Range: +10 dBm to 40 dBm Resolution: 1 dBm Background Noise, Harmonics and Spurious Signals: Refer to LEVEL AND FREQUENCY	Notch Filter: Greater than 50 dB rejection from 995 Hz to 1025 Hz For other specifications refer to MESSAGE CIRCUIT NOISE
NONLINEAR DISTORTION Test Signal Type: Two pairs of tones centered at 860 Hz and 1380 Hz Level Range: 0 dBm to −40 dBm Resolution: 1 dBm	Level Range: +10 dBm to −35 dBm Resolution: 1 dBm Accuracy: ±1 dBm 2nd Order Receive Filters: Centered at 520 Hz and 2240 Hz 3rd Order Receive Filter: Centered at 1900 Hz 2nd Order Products Range: To 50 dB below received level Accuracy: ±1 dB 3rd Order Products Range: To 60 dB below received level Accuracy: ±1 dB
P/AR Level Range: 0 dBm to 40 dBm Resolution: 1 dBm	Level Range: +10 dBm to −30 dBm Resolution: 1 dBm P/AR Range: 0 P/AR Units to 120 P/AR Units Resolution: 1 P/AR Unit Accuracy: ±2 P/AR Units
GENERAL Longitudinal Balance: 60 dB to 6 kHz, decreasing 6 dB per octave above 6 kHz Impedances: 600Ω and 900Ω Return Loss: Greater than 40 dB SF Skip: 2450 Hz to 2750 Hz	Longitudinal Balance: 60 dB to 6 kHz, decreasing 6 dB per octave above 6 kHz Terminating Impedances: 600Ω and 900Ω Bridging Impedance: Greater than 50 kΩ Bridging Loss: Less than 0.3 dB at 1 kHz Return Loss: Greater than 40 dB High Frequency Protection: Greater than 60 dB attenuation above 500 kHz

MONITOR AMPLIFIER OUTPUT Output Range: 0 volts to 7 volts Bandwidth (3 dB points). 200 Hz to 6200 Hz Frequency Response: ±1 dB from 300 Hz to 3900 Hz (Nominal values into loads of 150Ω or greater) Output Impedance: 5Ω Output Connector: 347 jack	**AUXILIARY OUTPUTS-BNC** Carrier: Square wave output of received frequency VCO. Nominal 10 kΩ source impedance. PM: AC signal proportional to band limited phase jitter. Nominal 10 kΩ source impedance.
MISCELLANEOUS Test Jacks: 310 jack multiplied with 5 way binding posts for both transmitter and receiver DC Blocking (with no holding). 200 volts Power Requirements: 105 to 129 volts AC, 60 Hz	Operating Temperature: 32°F to 122°F (0°C to 50°C) Storage Temperature: −40°F to 167°F (−40°C to 75°C) Warm-up Time for stated accuracy: 5 minutes

SECTION II INSTALLATION

2-1. INTRODUCTION.

2-2. This section contains information on unpacking and incoming inspection, input power requirements, mounting, checkout, and packing and shipping for the Transmission Impairment Measuring Set (TIMS).

2-3. UNPACKING AND INSPECTION.

2-4. Inspect the shipping container for damage. If the shipping container or cushioning material is damaged, it should be kept until the contents of the shipment have been checked for completeness and the unit has been checked mechanically and electrically. Procedures for checking electrical performance are given in paragraph 2-12. If the contents are incomplete, if there is mechanical damage or defect, or if the unit does not pass the electrical performance test, notify the nearest Hewlett-Packard office (listed in the back of this manual). If the shipping container is damaged, or the cushioning material shows signs of stress, notify the carrier as well as the Hewlett-Packard office. Keep the shipping materials for carrier's inspection. The HP office will arrange for repair or replacement without waiting for claim settlement.

2-5. POWER REQUIREMENTS.

2-6. The test set operates on standard commercial 60 Hz power of between 105 and 129 volts.

2-7. POWER CORD.

2-8. To protect operating personnel, the test set panel and chassis must be grounded. This test set is equipped with a detachable three-conductor power cable (HP P/N 8120-1983) which, when connected to a properly grounded power receptacle, grounds the unit.

WARNING

Any interruption of the protective (grounding) conductor (inside or outside the instrument) or disconnecting the protective earth terminal can make this instrument dangerous. Intentional interruption is prohibited.

2-9. MOUNTING.

2-10. The standard TIMS is provided with plastic feet on the bottom and back to allow placement on any flat surface. If it is desired to rack mount the test set, then either option 019 (standard 19 in. rack mounting model) or option 023 (standard 23 in. rack mounting model) may be ordered at the time of initial purchase. Dimensions of both the standard model and the two rack mount models are given in the specifications table in the General Information section of this manual. To mount the test set in a 19 inch or 23 inch rack, proceed as follows:

a. Place the test set on a flat surface and lay it on its back so that the front panel is facing up. Remove the twelve existing screws holding the front panel to the test set case, located around the edge of the front panel.

b. Lay the rack mount adapter over the face of the front panel, being careful to align the four notches in the adapter with the front panel "roll bar" handles.

c. Secure the rack mount adapter and front panel to the case (see figure 2-1) using the twelve screws provided (6-32, 0.625 in., pan head, Pozi drive).

d. Lift the test set into its rack position, and install with eight screws (10-32, 0.625 in., flat head), brass washers (0.578 in. OD, 0.250 in. ID) and nylon washers (0.555 in. OD, 0.095 in. ID) (see figure 2-2).

2-11. The test set is air cooled by an exhaust fan mounted in the top cover of the case. The top cover also has cooling fins cast into it to provide convection cooling for the heat dissipating elements in the power supply circuitry.

CAUTION

Do not place any object, such as manuals, clipboards, etc., on top of the test set. Restriction of air from the fan or cooling fins can cause overheating and damage to the test set.

2-12. BEFORE-USE CHECKOUT.

2-13. To determine that the test set is electrically operational, perform the Self Check procedures as described in the Operation section of this manual. The self check procedures will determine if the test set is operating properly.

2-14. SHIPPING INSTRUCTIONS.

2-15. USING ORIGINAL PACKAGING.

2-16. The same container and packing material used in factory packaging can be obtained through Hewlett-Packard Sales and Service Offices listed at the back of this manual. If the test set is being returned to Hewlett-Packard for servicing, attach a tag indicating the type of service or repair required, return address, model number, option numbers, and full serial number. Also mark the container FRAGILE to assure careful handling. In any correspondence, refer to the test set by model number, option numbers, and full serial number.

2-17. USING OTHER PACKAGING.

2-18. The following general instructions should be used for repackaging with commercially available materials:

a. Wrap the test set in heavy paper or plastic. (If shipping to a Hewlett-Packard Sales and Service Office, attach a tag indicating the type of service required, return address, model number, option numbers, and full serial number.)

b. Use a strong shipping container. A double-wall carton made of 275 pound test material is adequate.

c. Use enough shock-absorbing material (3- to 4-inch layer) around all sides of the test set to provide firm cushioning and prevent movement inside the container.

d. Seal the shipping container securely and mark it FRAGILE to assure careful handling.

e. In any correspondence, refer to the test set by model number, option numbers, and full serial number.

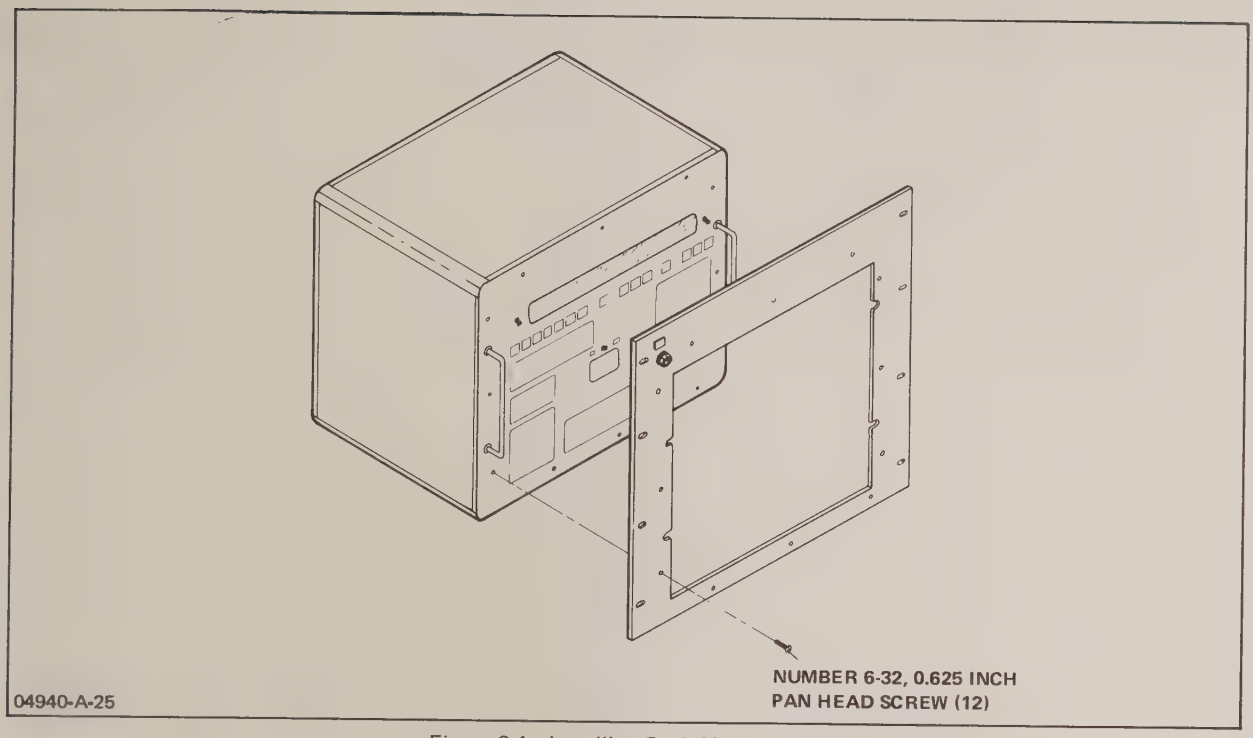


Figure 2-1. Installing Rack Mount Adapter

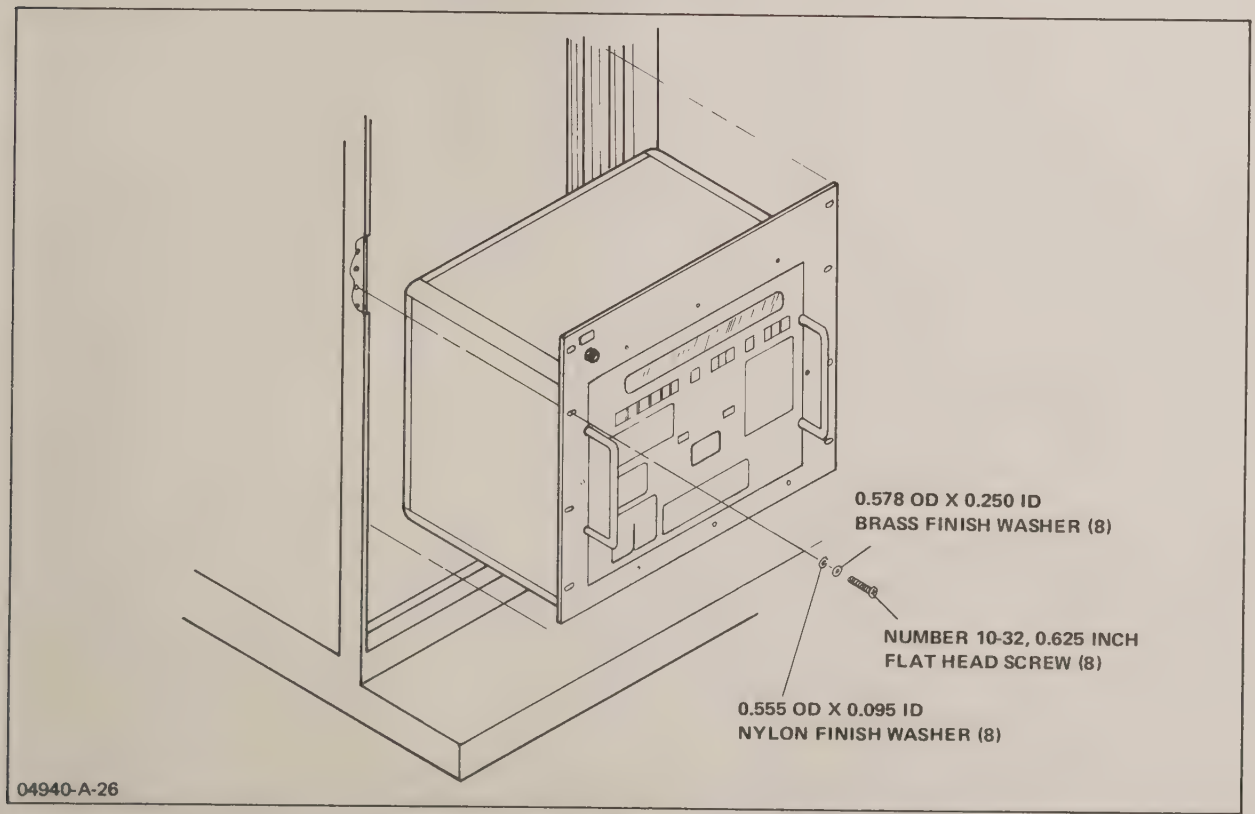
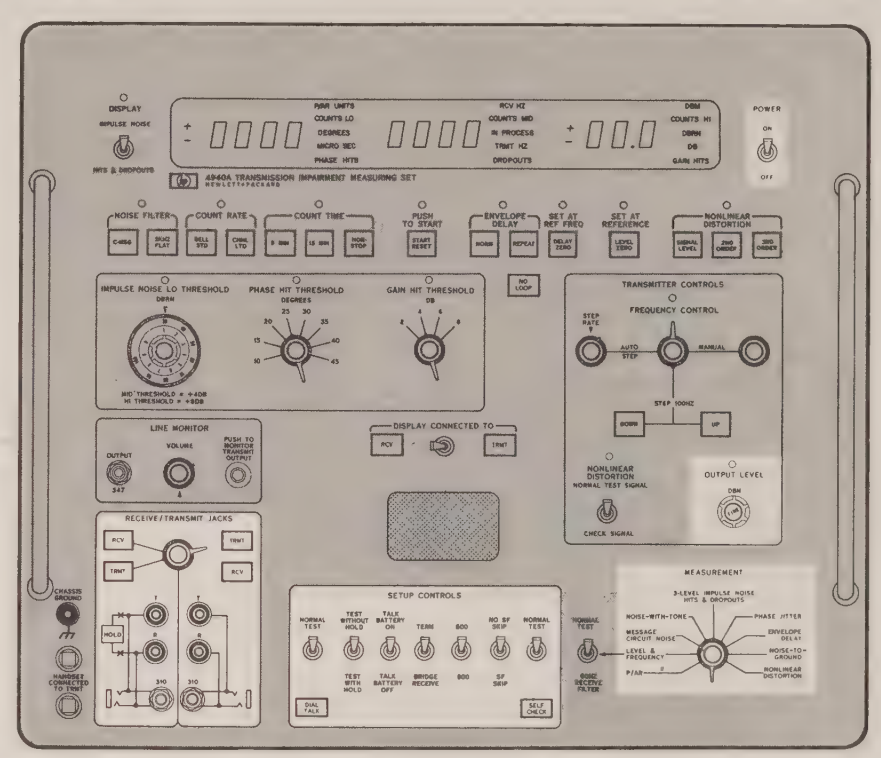


Figure 2-2. Installing TIMS Rack Mount Versions

SECTION III OPERATION

3-1. INTRODUCTION.

3-2. Operating instructions for the Transmission Impairment Measuring Set are covered in this section. Set-up and turn on procedures are covered in figure 3-1. Dial, talk, listen, and hold procedures are covered in figure 3-2. Parameter measurement procedures are covered in figures 3-3 through 3-20. Self check procedures are covered in figure 3-21. Lamp checks and replacement procedures are covered in figure 3-22. Finally, description of controls, connectors, and indicators is covered in figure 3-23.



SETUP AND TURN ON

1. Connect power cord to receptacle on top of test set and to 117 volts, 60Hz ac power line.

CAUTION

Do not place any object, such as manuals, clipboards, etc., on top of the test set. Restriction of air from the fan or cooling fins can cause overheating and damage to the test set.

2. Throw POWER switch to ON position to apply power to test set.
3. Throw SETUP CONTROLS key to BRIDGE RECEIVE if test set is to be bridged across receive line. Throw key to TERM if test set is to be used as termination on the receive line.
4. Throw SETUP CONTROLS key to 600 or 900 to match impedance of lines under test.
5. Throw SETUP CONTROLS key to SF SKIP if transmitting over a dial-up network and single frequency (SF) signaling units are on the network.
6. Throw far-right SETUP CONTROLS key to NORMAL TEST. Refer to SELF CHECK PROCEDURES (Figure 3-21) if it is desired to run self check procedure on test set.

NOTE

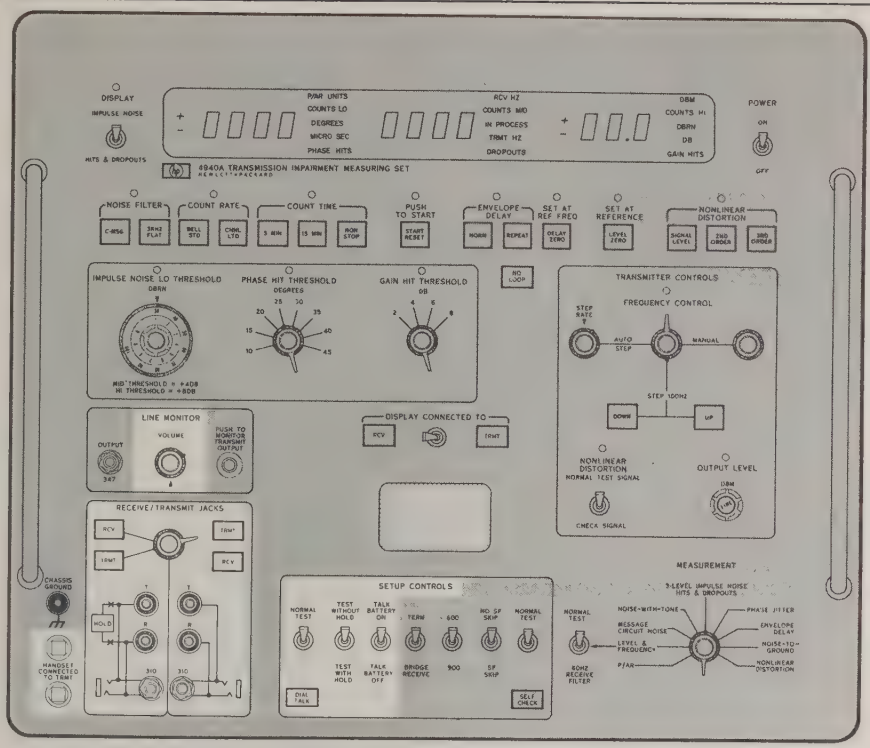
The self check procedure should be performed periodically to verify performance of the test set. SELF CHECK is recommended before transporting the test set to a remote testing site; or whenever there is any doubt about transmission measurement results.

7. Rotate OUTPUT LEVEL control full counterclockwise.
8. Rotate RECEIVE/TRANSMIT JACKS switch to select whether left jack field is to be used for TRMT or RCV. Connect transmit and receive lines (if both are required) to the appropriate TRANSMIT/RECEIVE JACKS. Refer to DIAL, TALK, LISTEN, and HOLD PROCEDURES (Figure 3-2) for proper hookup and control operation if dialing, talking, listening or holding are necessary on the lines under test.
9. Select desired MEASUREMENT mode and refer to appropriate measurement instructions section.

NOTE

The MEASUREMENT switch turns on indicator dot lamps over control groups that are active for that particular measurement. These lamps are a special aid to the selection of push-button switches. If an improper condition (i.e., all or no push-buttons depressed) exists in an active switch group, all indicator dot lamps and the display will go out, except the indicator dot lamp over the group that requires a selection.

Figure 3-1. Setup and Turn On Procedures



DIAL, TALK, LISTEN, AND HOLD

1. Perform SETUP AND TURN ON PROCEDURES (Figure 3-1) through Step 8.
2. Connect lineman's handset (butt-in) to HANDSET CONNECTED TO TRMT connector posts.
3. Refer to table below for proper hookup and control settings.

NOTE

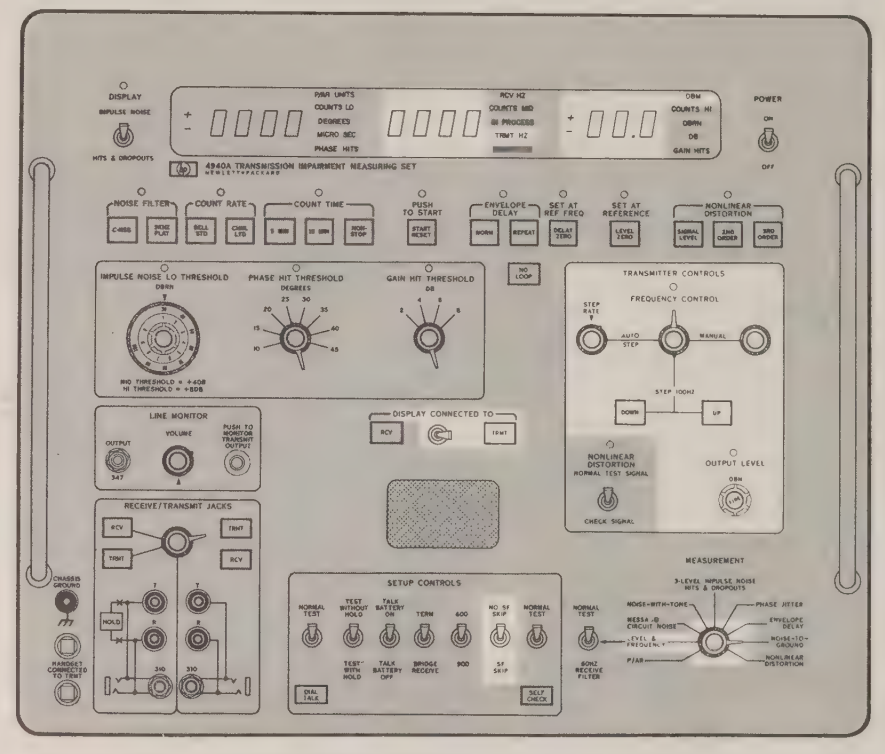
When going to NORMAL TEST mode on 2-wire wet (DDD) line, make sure SETUP CONTROLS key is in TEST WITH HOLD position before switching to NORMAL TEST. Failure to do so will cause the dial-up connection to be lost.

4. To return to talk or listen mode after normal tests are in progress, throw SETUP CONTROLS key to DIAL/TALK. Rotate RECEIVE/TRANSMIT JACKS switch as indicated for 2-wire circuits.

HOOKUP AND SETUP CONTROL SETTINGS FOR DIALING, TALKING, LISTENING, HOLDING AND TESTING

MODE	CIRCUIT		
	2-Wire Wet (DDD)	2-Wire Dry (DAA)	4-Wire Dry
HOOKUP	Transmit line connected to left RECEIVE/TRANSMIT JACKS	Transmit line connected to right RECEIVE/TRANSMIT JACKS	Transmit line connected to either RECEIVE/TRANSMIT JACKS
DIAL	DIAL/TALK; TALK BATTERY OFF; TEST WITHOUT HOLD; LEFT JACK TO TRMT (Dial with butt-in)		
TALK	DIAL/TALK; TALK BATTERY OFF; TEST WITH HOLD; LEFT JACK TO TRMT (Talk through butt-in)	DIAL/TALK; TALK BATTERY ON; TEST WITHOUT HOLD; RIGHT JACK TO TRMT (Talk through butt-in)	DIAL/TALK; TALK BATTERY ON; TEST WITHOUT HOLD (Talk through butt-in)
LISTEN	DIAL/TALK; TALK BATTERY OFF; TEST WITH HOLD; LEFT JACK TO TRMT (Listen through butt-in)	DIAL/TALK; TALK BATTERY ON; TEST WITHOUT HOLD; RIGHT JACK TO TRMT (Listen through butt-in)	Adjust LINE MONITOR as required (Listen through LINE MONITOR speaker)
TEST	TALK BATTERY OFF; TEST WITH HOLD; NORMAL TEST (Throw TEST WITH HOLD key before throwing NORMAL TEST key); LEFT JACK TO RCV IF RCV TEST SET	TALK BATTERY ON; TEST WITHOUT HOLD; NORMAL TEST; RIGHT JACK TO RCV IF RCV TEST SET	TALK BATTERY ON; TEST WITHOUT HOLD; NORMAL TEST

Figure 3-2. Dial, Talk, Listen, and Hold Procedures



LEVEL & FREQUENCY TRANSMITTER

1. Rotate MEASUREMENT switch to LEVEL & FREQUENCY.
2. Throw DISPLAY CONNECTED TO key to TRMT.
3. Rotate FREQUENCY CONTROL switch to STEP 100 HZ. Set transmit frequency to 1004 Hz by pressing DOWN or UP push-buttons, while observing TRMT HZ on center display.
4. Adjust OUTPUT LEVEL control for "Data Level" while observing DBM output level on right display.

DATA LEVEL

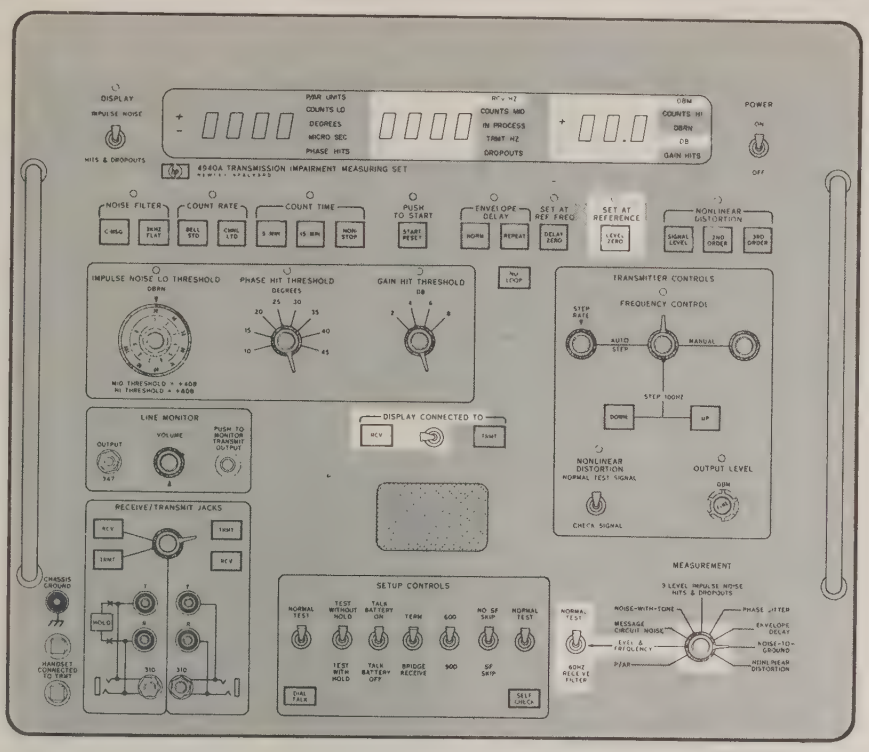
All transmission measurements should be made at Data Level. The Data Level for all presently specified data circuits is a power 13dB below the Transmission Level Point (TLP). For example, if the TLP is −16dB, the Data Level would be −29dBm. Therefore, an output level of −29dBm would be applied in this case.

5. When requested by the receiver operator, transmit the agreed upon test frequencies. When in the STEP 100 HZ FREQUENCY CONTROL mode, frequencies of 204Hz to 3904Hz can be selected in 100Hz increments by pressing the DOWN or UP push-buttons. Frequencies can also be stepped 100Hz automatically by rotating the FREQUENCY CONTROL switch to AUTO STEP and adjusting the STEP RATE control for the desired stepping rate. Frequencies other than those at the step points can be selected by rotating the FREQUENCY CONTROL switch to MANUAL and adjusting the MANUAL control for the desired frequency.

NOTE

If SF signaling units are used in the network under test, the SETUP CONTROLS key should be thrown to SF SKIP. This mode automatically blanks the transmitter output so that frequencies between 2450Hz and 2750Hz cannot be transmitted.

Figure 3-3. Level and Frequency Measurements, Transmitter



LEVEL & FREQUENCY
RECEIVER

1. Rotate MEASUREMENT switch to LEVEL & FREQUENCY.
2. Throw DISPLAY CONNECTED TO key to RCV.

1000 HZ LOSS MEASUREMENT

3. Instruct transmitter operator to send 1004 Hz tone.
4. Observe RCV HZ (nominally 1004 Hz) on center display and DBM received level on right display.
5. Depress 60 HZ RECEIVE FILTER key while observing DBM received level display. If received level changes more than ± 0.2 dBm, the 60 HZ RECEIVE FILTER key should be depressed throughout the measurement run.

FREQUENCY SHIFT MEASUREMENT

6. Observe RCV HZ while communicating with transmitter operator, comparing any difference between the transmitted and received frequency. The transmitting test set must be a TIMS, or other set capable of transmitting a signal known to within ±0.5 Hz.

ATTENUATION DISTORTION MEASUREMENT

7. Press LEVEL ZERO push-button while receiving the reference frequency (e.g., 1004 Hz). This establishes a 0 dB reference.
8. Observe RCV HZ on center display and ±DB relative loss on right display as agreed upon frequencies are transmitted. +DB indicates more loss and −DB indicates less loss, relative to the reference frequency.

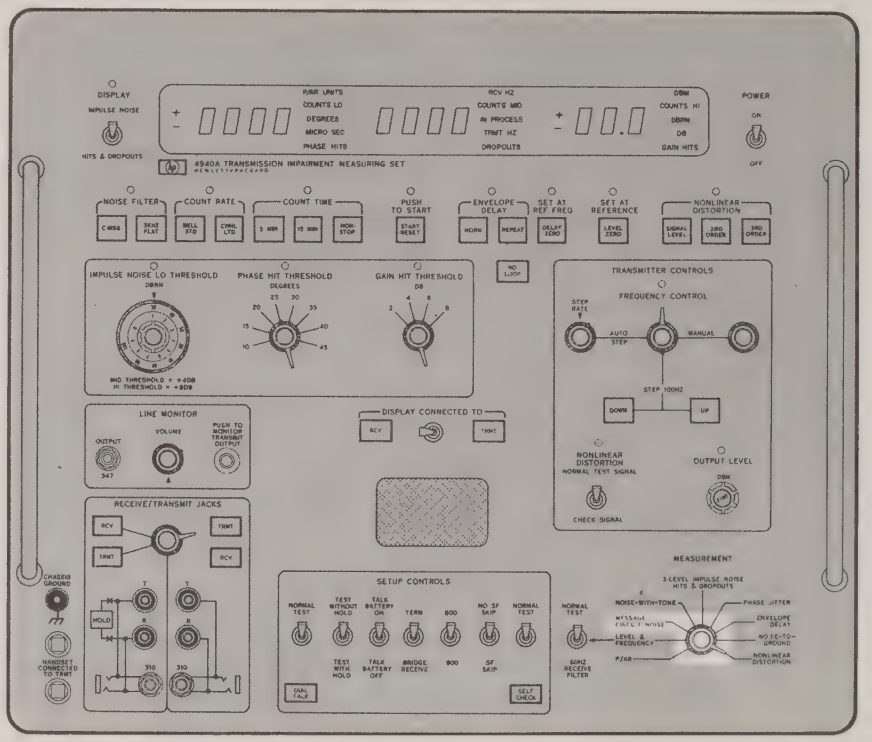
NOTE

If SF signaling units are used in the network under test, the transmitting test set should be operated in the SF SKIP mode. In this mode there will be no test signal as the transmitter frequency is adjusted through the 2450 Hz to 2750 Hz range.

NOTE

Attenuation distortion measurements can also be made in absolute dBm units, if desired. The test set is automatically in the dBm mode until the LEVEL ZERO push-button is pressed. To return the test set to the dBm mode, momentarily rotate the MEASUREMENT switch out of the LEVEL & FREQUENCY position, then back again.

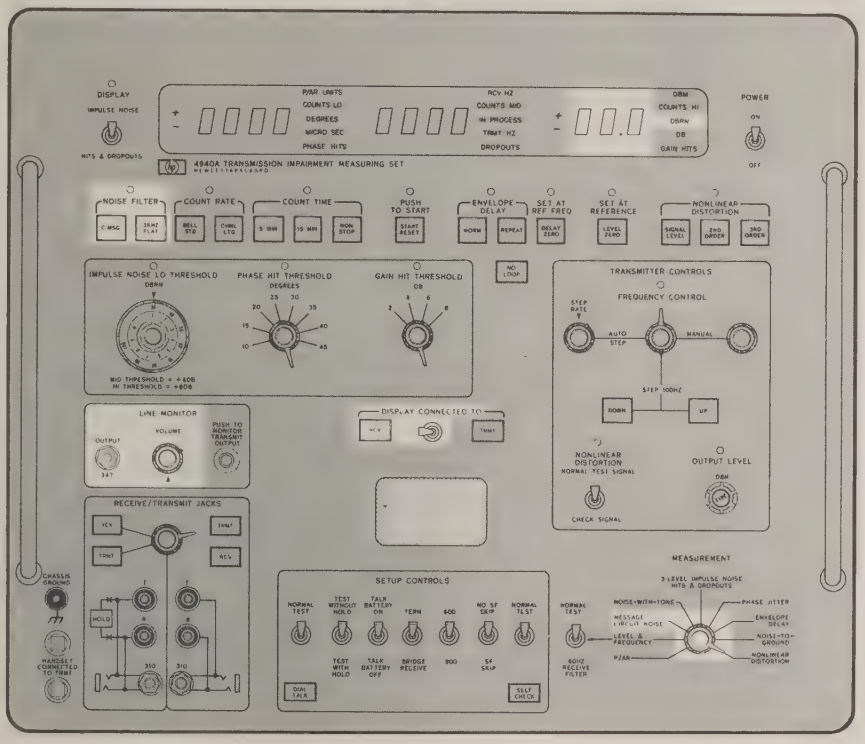
Figure 3-4. Level and Frequency Measurements, Receiver



MESSAGE CIRCUIT NOISE
TRANSMITTER

1. Rotate MEASUREMENT switch to MESSAGE CIRCUIT NOISE. This provides the TRMT jacks with a quiet termination.

Figure 3-5. Message Circuit Noise Measurements, Transmitter



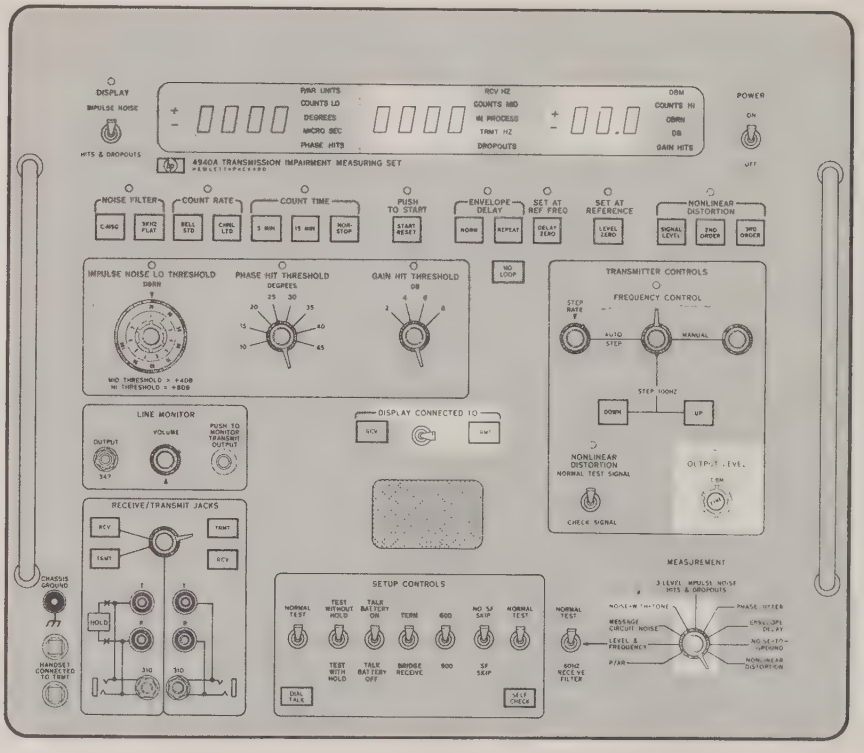
MESSAGE CIRCUIT NOISE
RECEIVER

1. Rotate MEASUREMENT switch to MESSAGE CIRCUIT NOISE.
2. Throw DISPLAY CONNECTED TO key to RCV.
3. Depress NOISE FILTER push-button (C-MSG or 3 KHZ FLAT) to select desired weighting.
4. Observe DBRN noise level on right display.

SINGLE FREQUENCY INTERFERENCE CHECK

5. Turn on LINE MONITOR by rotating VOLUME control until desired loudness is obtained in speaker or headphones. Listen for any predominant tone which will indicate a potential single frequency interference problem. A frequency selective voltmeter, spectrum analyzer, oscilloscope, etc., can be connected to the LINE MONITOR OUTPUT jack to further analyze the frequency and level of the interfering tone.

Figure 3-6. Message Circuit Noise Measurements, Receiver



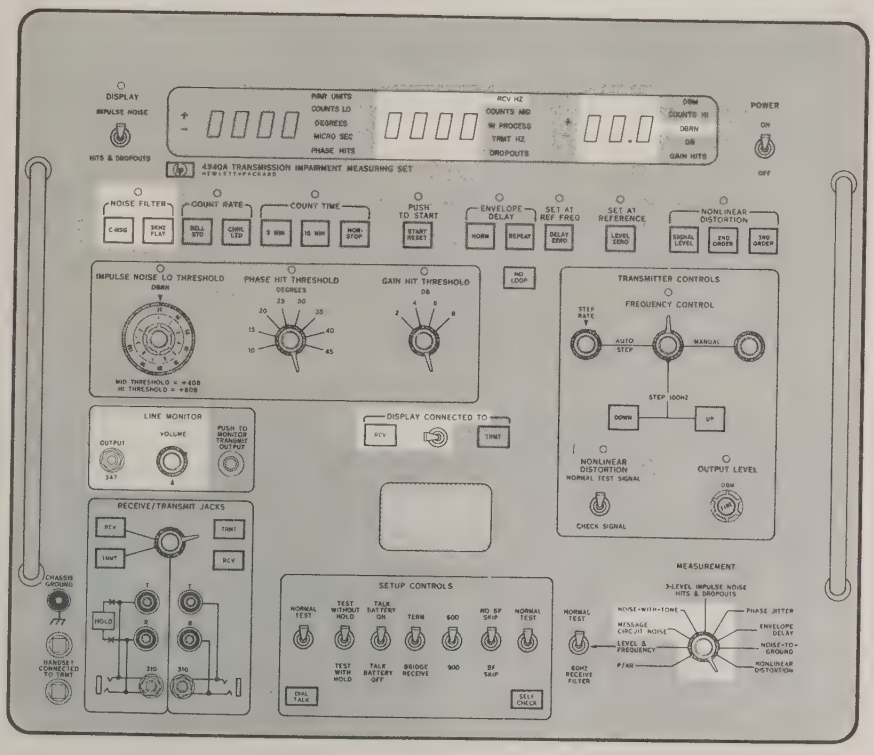
NOISE-WITH-TONE TRANSMITTER

1. Rotate MEASUREMENT switch to NOISE-WITH-TONE.
2. Throw DISPLAY CONNECTED TO key to TRMT.
3. Observe TRMT HZ on center display to verify that 1004 Hz holding tone is being transmitted.
4. Adjust OUTPUT LEVEL control for "Data Level" while observing DBM on right display.

DATA LEVEL

All transmission measurements should be made at Data Level. The Data Level for all presently specified data circuits is a power 13 dB below the Transmission Level Point (TLP). For example, if the TLP is −16 dB, the Data Level would be −29 dBm. Therefore, an output level of −29 dBm would be applied in this case.

Figure 3-7. Noise-with-Tone Measurements, Transmitter



NOISE-WITH-TONE RECEIVER

1. Rotate MEASUREMENT switch to NOISE-WITH-TONE.
2. Throw DISPLAY CONNECTED TO key to RCV.
3. Depress NOISE FILTER push-button (C-MSG or 3 KHZ FLAT) to select desired weighting.
4. Observe RCV HZ on center display to verify that holding tone between 995 Hz and 1025 Hz is being received.
5. Turn on LINE MONITOR by rotating VOLUME control until desired loudness is obtained in speaker or headphones. Listen for any predominant tone which will indicate a potential single frequency interference problem.
6. Observe DBRN noise level on right display.

SIGNAL-TO-NOISE MEASUREMENT AND CALCULATION

7. Depress C-MSG NOISE FILTER push-button.
8. Observe DBRN noise level on right display and note this value.
9. Rotate MEASUREMENT switch to MESSAGE CIRCUIT NOISE.
10. Observe DBRN tone level on right display and note this value.
11. Subtract noise level noted in step 8 from tone level noted in step 10. The result is SIGNAL-TO-NOISE in dB.

Example:

Tone level (step 10)	74dBrn
–Noise level (step 8)	–50dBrn
= SIGNAL-TO-NOISE	= 24dB

NOTE

This measurement cannot be made on a loop-around basis using one test set since it requires the transmitting test set to be set to NOISE-WITH-TONE while the receiving test set is set to MESSAGE CIRCUIT NOISE.

Figure 3-8. Noise-with-Tone Measurements, Receiver

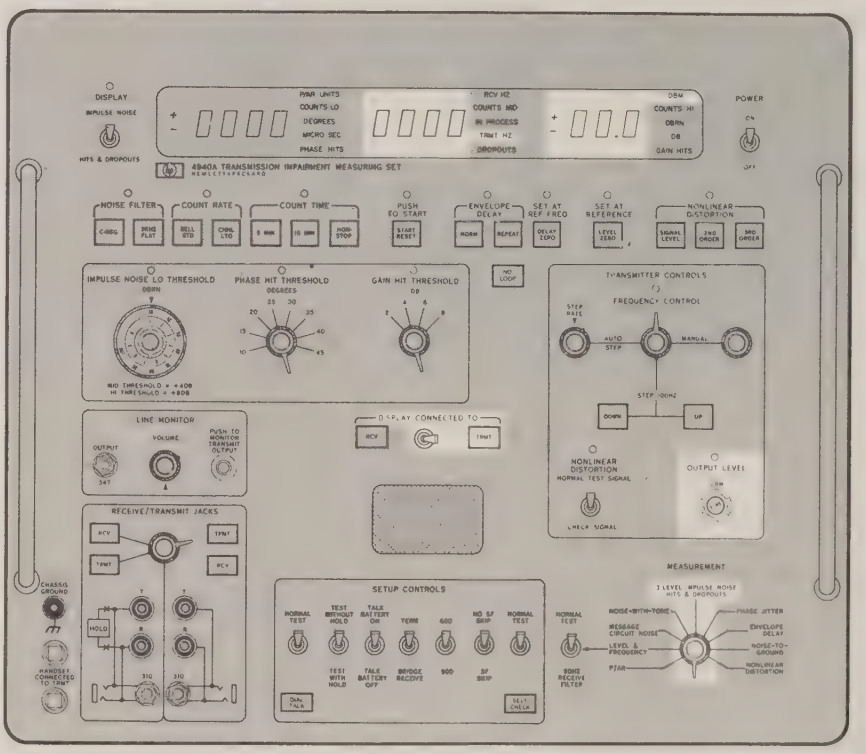


Figure 3-9. 3-Level Impulse Noise, Hits and Dropouts Measurements, Transmitter (Sheet 1 of 2)

3-LEVEL IMPULSE NOISE, HITS & DROPOUTS TRANSMITTER

1. Rotate MEASUREMENT switch to 3-LEVEL IMPULSE NOISE HITS & DROPOUTS.
2. Throw DISPLAY CONNECTED TO key to TRMT.
3. Observe TRMT HZ on center display to verify that 1004 Hz is being transmitted.
4. Adjust OUTPUT LEVEL control for "Data Level" while observing DBM on right display.

DATA LEVEL

All transmission measurements should be made at Data Level. The Data Level for all presently specified data circuits is a power 13dB below the Transmission Level Point (TLP). For example, if the TLP is −16dBm, the Data Level would be −29dBm. Therefore, an output level of −29dBm would be applied in this case.

Figure 3-9. 3-Level Impulse Noise, Hits and Dropouts Measurements, Transmitter (Sheet 2 of 2)

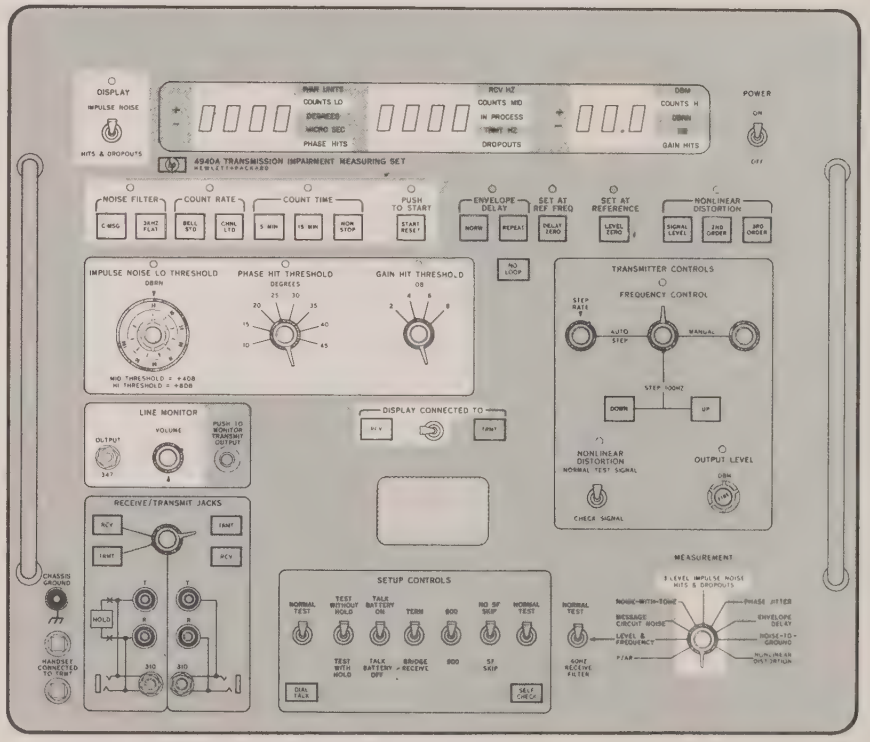


Figure 3-10. 3-Level Impulse Noise, Hits and Dropouts Measurements, Receiver (Sheet 1 of 2)

3-LEVEL IMPULSE NOISE, HITS & DROPOUTS RECEIVER

1. Rotate MEASUREMENT switch to 3-LEVEL IMPULSE NOISE HITS & DROPOUTS.
2. Throw DISPLAY CONNECTED TO key to RCV.
3. Depress NOISE FILTER push-button (C-MSG or 3 KHZ FLAT) to select desired weighting.
4. Depress COUNT RATE push-button (BELL STD or CHNL LTD).
5. Depress COUNT TIME push-button (5 MIN, 15 MIN, or NON-STOP).
6. Rotate IMPULSE NOISE LO THRESHOLD switches to setting specified for the circuit under test.

NOTE

The general rule for determining the IMPULSE NOISE LO THRESHOLD setting is to add the threshold setting in dBrnCo (from the System Practice) to the TLP at the point of measurement.

7. Rotate PHASE HIT THRESHOLD switch to setting specified for the circuit under test.

NOTE

PHASE HIT THRESHOLD setting of 20 DEGREES recommended for most circuits. Consult applicable System Practice for specific recommendations.

8. Rotate GAIN HIT THRESHOLD switch to setting specified for the circuit under test.
9. Press START RESET push-button. The IN PROCESS annunciator will light for the duration of the count time.

NOTE

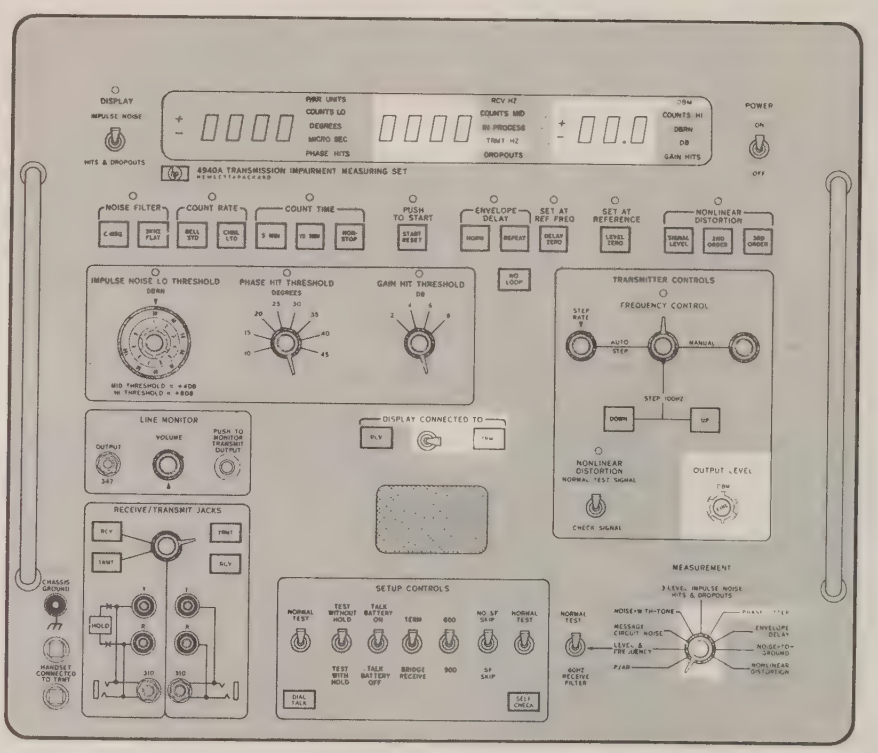
The (—) sign in the right display may light up momentarily after the START RESET button is pressed and during counting whenever a dropout is counted. This is normal. However, if the (—) sign remains lighted, it is an indication that the proper test tone is not being received.

10. Turn on LINE MONITOR by rotating VOLUME control until desired loudness is obtained in speaker or headphones. Listen for any predominant noise which can provide a clue as to the noise source.
11. At any time during or after the count time, the accumulated counts for impulse noise can be observed by throwing the DISPLAY key to IMPULSE NOISE. GAIN HITS, PHASE HITS, and DROPOUTS can be observed by throwing the DISPLAY key to HITS & DROPOUTS.
12. When the IN PROCESS annunciator goes out the total counts for the measurements period can be observed.

NOTE

To stop counting before the count time is expired (or when in NON-STOP) without erasing the display totals, rotate the threshold level switches to their maximum settings.

Figure 3-10. 3-Level Impulse Noise, Hits and Dropouts Measurements, Receiver (Sheet 2 of 2)



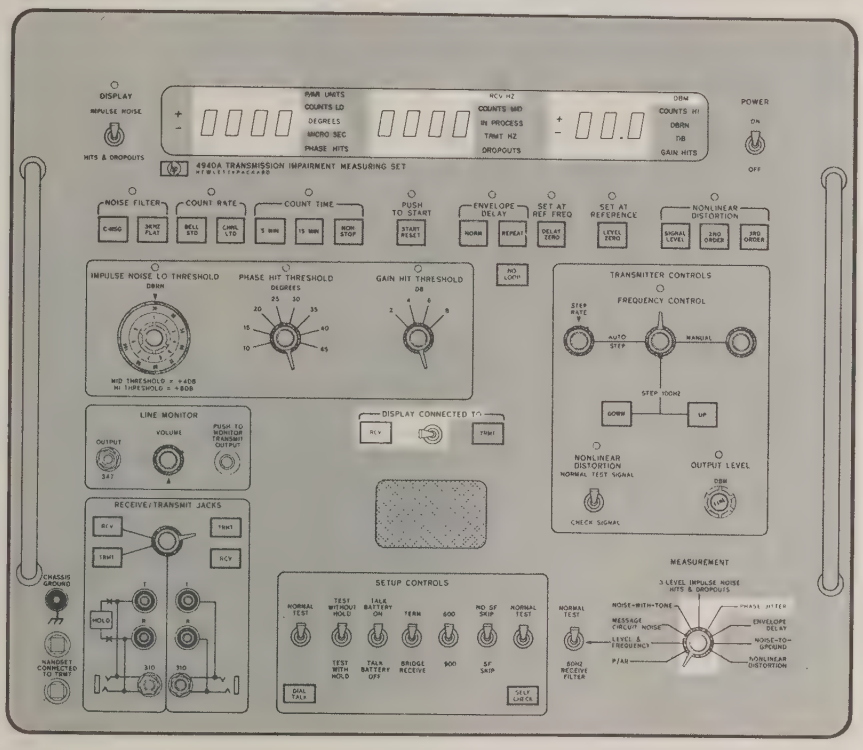
PHASE JITTER TRANSMITTER

1. Rotate MEASUREMENT switch to PHASE JITTER.
2. Throw DISPLAY CONNECTED TO key to TRMT.
3. Observe TRMT HZ on center display to verify that 1004 Hz is being transmitted.
4. Adjust OUTPUT LEVEL control for "Data Level" while observing DBM on right display.

DATA LEVEL

All transmission measurements should be made at Data Level. The Data Level for all presently specified data circuits is a power 13 dB below the Transmission Level Point (TLP). For example, if the TLP is −16 dB, the Data Level would be −29 dBm. Therefore, an output level of −29 dBm would be applied in this case.

Figure 3-11. Phase Jitter Measurements, Transmitter



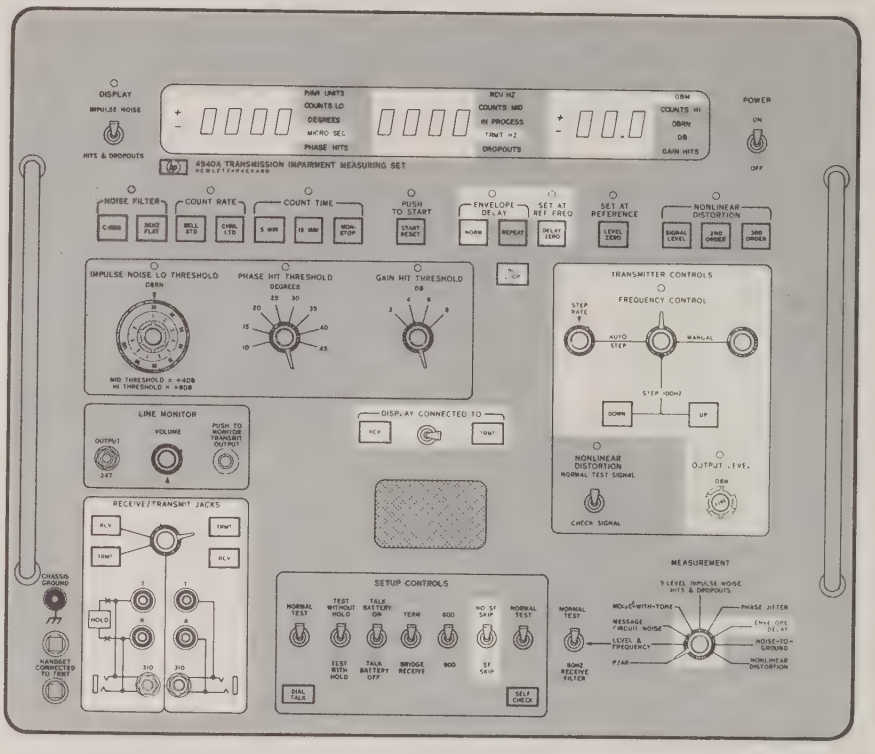
PHASE JITTER
RECEIVER

1. Rotate MEASUREMENT switch to PHASE JITTER.
2. Throw DISPLAY CONNECTED TO key to RCV.
3. Observe DBM received level on right display. This level must be −40dBm or greater for a valid measurement to be made.
4. Observe RCV HZ on center display. This frequency must be between 990Hz and 1030Hz.
5. Observe DEGREES phase jitter on left display. If the readings vary, observe for an arithmetic mean (average). [Display of only a (+) sign indicates that phase jitter is more than 25°.]

NOTE

Further analysis of phase jitter can be performed using auxiliary instruments. Signals as described on page 3-35 are available for this purpose.

Figure 3-12. Phase Jitter Measurements, Receiver



ENVELOPE DELAY
NORMAL TEST SET

1. Connect line to be tested to TRMT jack and connect return reference line to RCV jack.
2. Rotate MEASUREMENT switch to ENVELOPE DELAY.
3. Throw DISPLAY CONNECTED TO key to TRMT.
4. Depress NORM ENVELOPE DELAY push-button.
5. Adjust OUTPUT LEVEL control for "Data Level" while observing DBM on right display.

DATA LEVEL

All transmission measurements should be made at Data Level. The Data Level for all presently specified data circuits is a power 13dB below the Transmission Level Point (TLP). For example, if the TLP is −16dB, the Data Level would be −29dBm. Therefore, an output level of −29dBm would be applied in this case.

6. When the Repeat Test Set operator notifies you that he has adjusted to the desired transmission frequency (his Step 6 if Repeat Test Set is a TIMS), throw DISPLAY CONNECTED TO key to RCV.
7. Notify Repeat Test Set operator that you have completed your Step 6.

Figure 3-13. Envelope Delay Measurements, Normal Test Set (Sheet 1 of 2)

NOTE

Although the DISPLAY CONNECTED TO key is in the RCV mode, the center display will indicate TRMT HZ since this is the frequency of interest to the Normal Test Set operator.

8. Observe DBM on right display. This level must be −40dBm or greater for valid measurements.
9. Observe that NO LOOP annunciator is not lit.
10. Rotate FREQUENCY CONTROL switch to STEP 100HZ and set TRMT HZ on center display to reference frequency by pressing DOWN or UP push-buttons (e.g., 1804Hz, or frequency of minimum delay). Frequency can be set in MANUAL FREQUENCY CONTROL mode if necessary.
11. Observe ± MICRO SEC on left display. This reading may be very erratic for a few seconds until the loop stabilizes. When the display stabilizes so that only the units and tens digits are changing, press the DELAY ZERO push-button.

NOTE

This establishes a reference zero at the reference frequency. Typically, this reading will vary ±20 MICRO SEC. However, on very noisy circuits, the variation may be greater. A valid reference zero is established if these variations are evenly distributed above and below zero microseconds.

12. Observe TRMT HZ on center display. Select the desired test frequencies by pressing the STEP 100 HZ DOWN or UP push-buttons. Frequencies can also be stepped 100Hz automatically by rotating the FREQUENCY CONTROL switch to AUTO STEP and adjusting the STEP RATE control for the desired stepping rate. Frequencies other than those at the step points can be selected by rotating the FREQUENCY CONTROL switch to MANUAL and adjusting the MANUAL control for the desired frequency.

NOTE

If SF signaling units are used in the network under test, the SETUP CONTROLS key should be thrown to SF SKIP. This mode automatically blanks the transmitter output so that frequencies between 2450Hz and 2750Hz cannot be transmitted.

13. At each test frequency, observe ±MICRO SEC envelope delay on left display. If the readings vary, observe for an arithmetic mean (average).

NOTE

There are two conditions under which the test set will indicate to the operator that a valid envelope delay measurement cannot be made:

a. Under Range Condition: If the received level drops below −49dBm all three displays will blank and a (−) sign will appear in the right display. Usually the NO LOOP annunciator will also light up. This is a normal condition when the test set is in SF SKIP mode and the transmitter frequency controls are set in the 2450Hz to 2750Hz range. To clear this condition, merely readjust the frequency to outside the skip range. Measurements can proceed as soon as the MICRO SEC display stabilizes.

b. NO LOOP Condition: If the 83-1/3 Hz modulation frequency is lost the NO LOOP annunciator will light up. Whenever there is a signal loss due to a broken loop, the cause must be identified and corrected. When the loop is restored, measurements can proceed as soon as the MICRO SEC display stabilizes.

NOTE

The reference delay zero will be lost if the Normal Test Set's MEASUREMENT switch or DELAY ZERO push-button are disturbed. It will be necessary to return to Steps 10 and 11 to re-establish the reference zero.

Figure 3-13. Envelope Delay Measurements, Normal Test Set (Sheet 2 of 2)

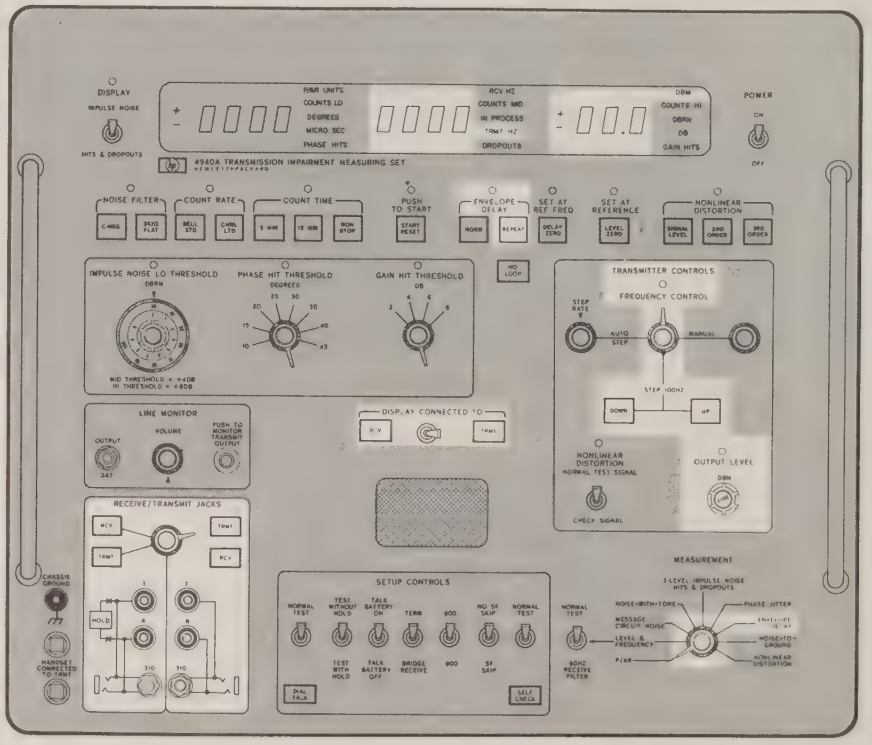


Figure 3-14. Envelope Delay Measurements, Repeat Test Set (Sheet 1 of 2)

ENVELOPE DELAY
REPEAT TEST SET

1. Connect line to be tested to RCV jack and connect return reference line to TRMT jack.
2. Rotate MEASUREMENT switch to ENVELOPE DELAY.
3. Throw DISPLAY CONNECTED TO key to TRMT.
4. Depress REPEAT ENVELOPE DELAY push-button.
5. Adjust OUTPUT LEVEL control for "Data Level" while observing DBM on right display.

DATA LEVEL

All transmission measurements should be made at Data Level. The Data Level for all presently specified data circuits is a power 13dB below the Transmission Level Point (TLP). For example, if the TLP is −16dB, the Data Level would be −29dBm. Therefore, an output level of −29dBm would be applied in this case.

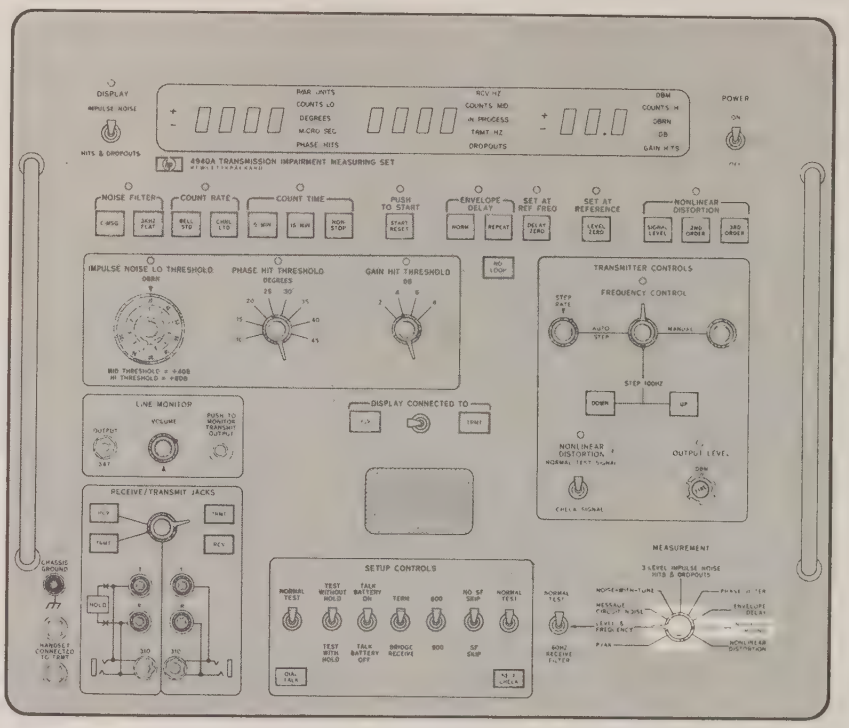
6. Rotate FREQUENCY CONTROL switch to STEP 100 HZ and set TRMT HZ on center display for desired transmission frequency on reference channel (e.g., 1804Hz) by pressing DOWN or UP push-buttons.
7. Notify Normal Test Set operator that you have completed your Step 6.
8. When Normal Test Set operator notifies you that he has completed his Step 6 (if Normal Test Set is a TIMS), throw DISPLAY CONNECTED TO key to RCV.

NOTE

If the DISPLAY CONNECTED TO key is thrown back to TRMT at any time during the envelope delay measurements, the loop will be broken and the Normal Test Set will display erroneous measurement information.

9. Monitor DBM received level on right display to be sure it remains −40dBm or greater throughout the measurements.

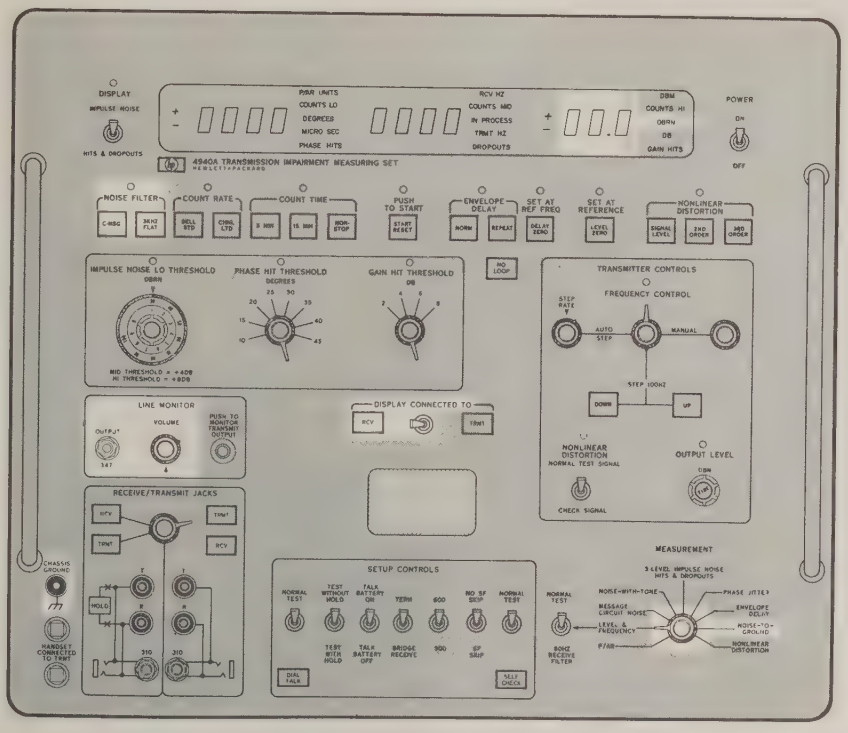
Figure 3-14. Envelope Delay Measurements, Repeat Test Set (Sheet 2 of 2)



NOISE-TO-GROUND TRANSMITTER

1. Rotate MEASUREMENT switch to NOISE-TO-GROUND. This provides the TRMT jacks with a quiet termination.

Figure 3-15. Noise-to-Ground Measurements, Transmitter



NOISE-TO-GROUND RECEIVER

NOTE

The test set must be properly grounded for valid noise-to-ground measurements. Ground can be established through the power cord ground if there is a reliable power line bond; through the sleeve connections on the 310 RECEIVE/TRANSMIT JACKS; or by connecting the CHASSIS GROUND post to a known good ground.

1. Rotate MEASUREMENT switch to NOISE-TO-GROUND.
2. Throw DISPLAY CONNECTED TO key to RCV.
3. Depress NOISE FILTER button (C-MSG or 3KHZ FLAT) to select desired weighting.
4. Observe DBRN noise level on right display.

NOTE

TIMS provides actual noise-to-ground readings in dBrn. It is not necessary to add 40dB to the readings.

5. Turn on LINE MONITOR by rotating VOLUME control until desired loudness is obtained in speaker or headphones. Listen for any predominant tone which can provide a clue as to the noise source.

NOTE

This measurement is valid only on metallic (physical) circuits (end loops).

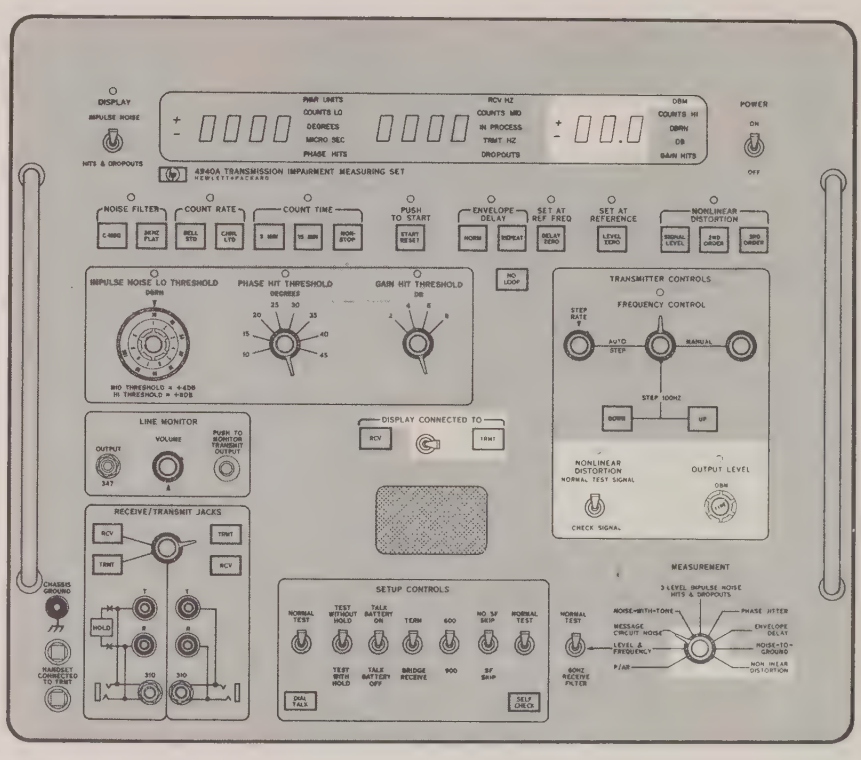
LINE BALANCE CALCULATION

6. A figure of merit for line balance can be calculated by measuring message circuit noise (N_m) and noise-to-ground (N_g) and applying the formula: Balance in dB = $N_m - N_g$ *(Note that it is not necessary to add 40dB to N_g in this equation.)*

NOTE

It is recommended that both of these measurements be made using the 3KHZ FLAT NOISE FILTER to account for the effects of power line related noise.

Figure 3-16. Noise-to-Ground Measurements, Receiver



NONLINEAR DISTORTION (Optional)
TRANSMITTER

1. Rotate MEASUREMENT switch to NONLINEAR DISTORTION.
2. Throw DISPLAY CONNECTED TO key to TRMT.
3. Adjust OUTPUT LEVEL control for "Data Level" while observing DBM on right display.

DATA LEVEL

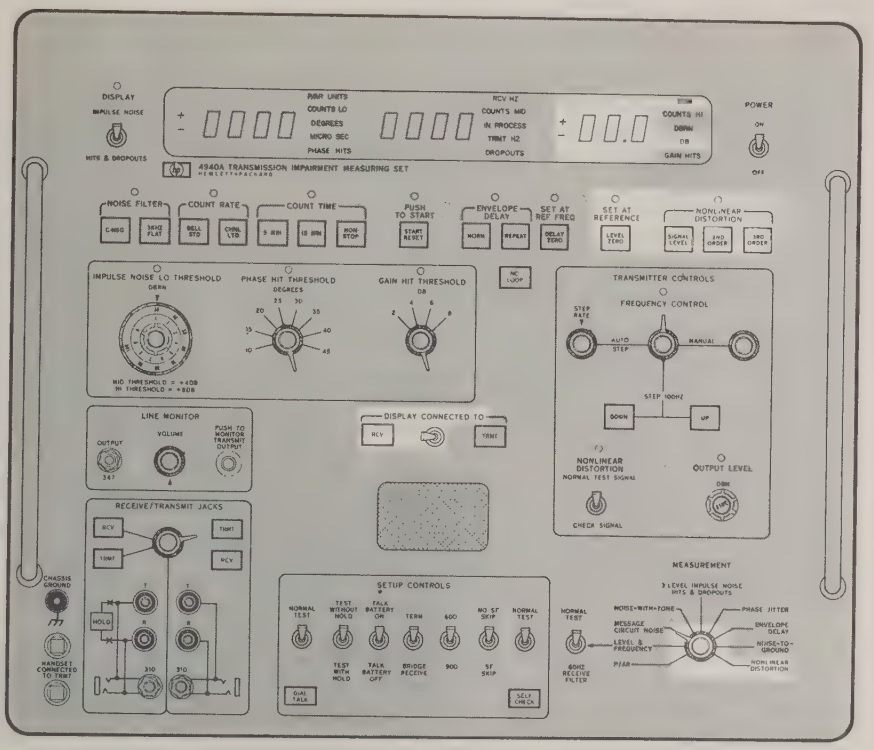
All transmission measurements should be made at Data Level. The Data Level for all presently specified data circuits is a power 13dB below the Transmission Level Point (TLP). For example, if the TLP is −16dB, the Data Level would be −29dBm. Therefore, an output level of −29dBm would be applied in this case.

NOTE

Maximum output level for nonlinear distortion is 0dBm.

4. When requested by receiver operator, hold NONLINEAR DISTORTION key in CHECK SIGNAL position.

Figure 3-17. Nonlinear Distortion Measurements, Transmitter



NONLINEAR DISTORTION (Optional)
RECEIVER

1. Rotate MEASUREMENT switch to NONLINEAR DISTORTION.
2. Throw DISPLAY CONNECTED TO key to RCV.
3. Depress SIGNAL LEVEL push-button.
4. Observe DBM received level on right display. This level must be −35 dBm or greater for a valid measurement.

NOTE

The received level may take 15-20 seconds to stabilize.

5. Press LEVEL ZERO push-button. This establishes a 0dB reference so distortion products can be measured in dB relative to signal level.
6. Depress 2ND ORDER push-button.
7. Observe DB normal test signal level on right display (note this number).
8. Instruct transmitter operator to send CHECK SIGNAL.
9. Observe DB check signal level on right display (note this number).
10. Subtract check signal level reading (Step 9) from normal test signal level reading (Step 7). Refer to NOISE CORRECTION TABLE (use dB Relative column) and add the appropriate correction factor to the normal test signal reading. The result is NONLINEAR DISTORTION in dB.
11. Depress 3RD ORDER push-button and repeat Steps 7 through 10 to determine the 3rd order distortion level.

MEASURING DBM ABSOLUTE SIGNAL LEVEL

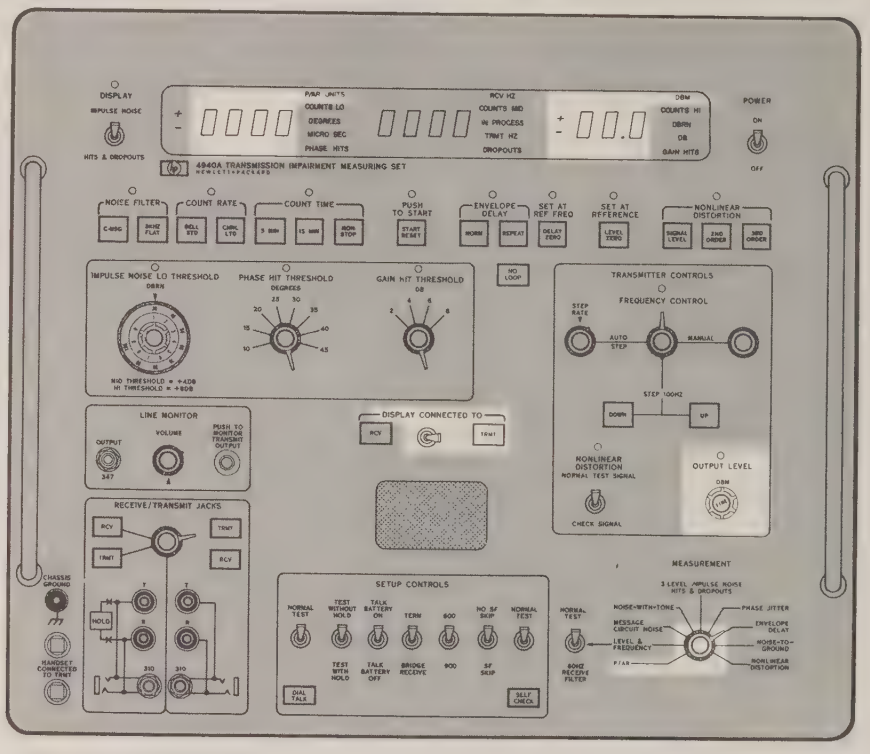
12. If measurement of distortion products directly in dBm is desired, do not perform Step 5. Proceed with Steps 6 through 11, observing DBM levels on right display. Use dBm Absolute column of NOISE CORRECTION TABLE and subtract the appropriate correction factor from the normal test signal reading.

NONLINEAR DISTORTION NOISE CORRECTION TABLE

Corrections to be made to 2nd and 3rd Order Nonlinear Distortion Measurements to correct for presence of noise		
dB difference between normal test signal and check signal readings	dB Relative Add to normal test signal reading	dBm Absolute Subtract from normal test signal reading
0	*	*
1	7	7
2	4	4
3	3	3
4-5	2	2
6-8	1	1
Over 8	0	0

*Zero difference indicates that distortion level is buried in noise. This can be interpreted as either extremely low distortion, or extremely high noise and should be further investigated.

Figure 3-18. Nonlinear Distortion Measurements, Receiver



P/AR (Optional) TRANSMITTER

1. Rotate MEASUREMENT switch to P/AR.
2. Throw DISPLAY CONNECTED TO key to TRMT.
3. Adjust OUTPUT LEVEL control for "Data Level" while observing DBM on right display.

DATA LEVEL

All transmission measurements should be made at Data Level. The Data Level for all presently specified data circuits is a power 13dB below the Transmission Level Point (TLP). For example, if the TLP is −16dB, the Data Level would be −29dBm. Therefore, an output level of −29dBm would be applied in this case.

NOTE

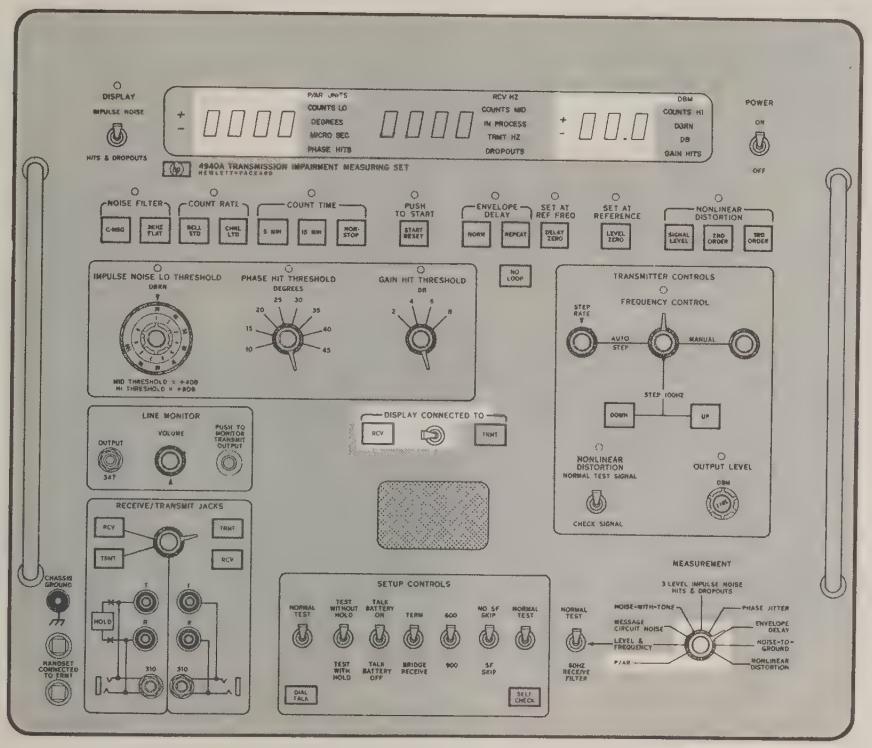
Maximum output for P/AR is 0 dBm.

4. Observe P/AR UNITS on left display and verify transmission of 99 to 101 P/AR units.

NOTE

The above P/AR measurement has been designed to improved specifications which overcome the effects of frequency translation and other phenomena; therefore, the TIMS P/AR measurement may not be compatible with other P/AR test sets.

Figure 3-19. P/AR Measurements, Transmitter



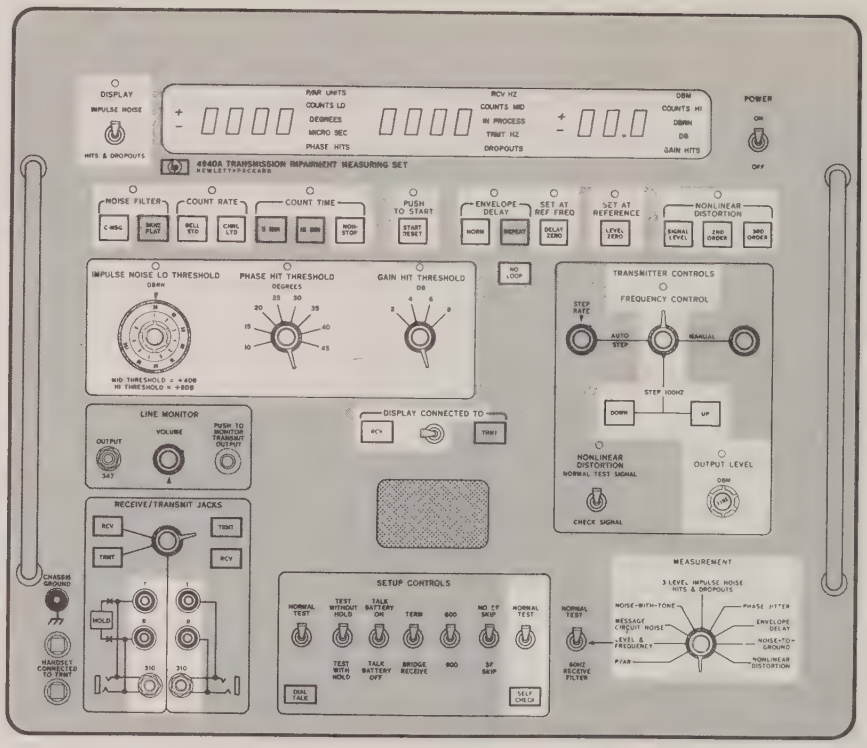
P/AR (Optional)
RECEIVER

1. Rotate MEASUREMENT switch to P/AR.
2. Throw DISPLAY CONNECTED TO key to RCV.
3. Observe DBM received level on right display. This level must be –40dBm or greater for a valid measurement.
4. Observe P/AR UNITS on left display.

NOTE

The above P/AR measurement has been designed to improved specifications which overcome the effects of frequency translation and other phenomena; therefore, the TIMS P/AR measurement may not be compatible with other P/AR test sets.

Figure 3-20. P/AR Measurements, Receiver



SELF-CHECK

NOTE

The SELF CHECK procedure should be performed periodically to verify performance of the test set. SELF CHECK is recommended before transporting the test set to a remote testing site; or whenever there is any doubt about transmission measurement results. Failure of the test set to pass any SELF CHECK indicates a malfunction that can possibly affect other measurements. It is therefore recommended that a complete SELF CHECK always be performed to determine which measurement modes are valid.

1. PRELIMINARY SETUP:
   a. Disconnect test set from on-line testing.
   b. Loop TRMT jack to RCV jack.
   c. Throw far right-hand SETUP CONTROLS key to SELF CHECK. Throw all other SETUP CONTROLS keys to up position.
   d. Throw DISPLAY CONNECTED TO key to RCV.

2. P/AR SELF CHECK (Optional):
   a. Rotate MEASUREMENT switch to P/AR.
   b. Verify a reading of 99 to 101 P/AR UNITS on left display.
   c. Verify a reading of −1 to +1 DBM on right display.

3. LEVEL & FREQUENCY SELF CHECK:
   a. Rotate MEASUREMENT switch to LEVEL & FREQUENCY.
   b. Rotate FREQUENCY CONTROL switch to STEP 100 HZ.
   c. Verify a reading of 1004 RCV HZ on center display.
   d. Verify a reading of −0.2 to +0.2 DBM on right display.

4. MESSAGE CIRCUIT NOISE AND INDICATOR LAMPS SELF CHECK:
   a. Rotate MEASUREMENT switch to MESSAGE CIRCUIT NOISE.
   b. Depress C-MSG NOISE FILTER push-button.
   c. Verify a reading of 89 to 91 DBRN on right display.
   d. Verify that all 15 indicator dot lamps are lit.

Figure 3-21. Self Check Procedures (Sheet 1 of 3)

5. NOISE-WITH-TONE SELF CHECK:
   a. Rotate MEASUREMENT switch to NOISE-WITH-TONE.
   b. Depress C-MSG NOISE FILTER push-button.
   c. Verify a reading of 58 to 62 DBRN on right display at the end of one minute.
   d. Verify a reading of 1003 to 1005 RCV HZ on center display.

6. 3-LEVEL IMPULSE NOISE HITS & DROPOUTS SELF-CHECK:
   a. Rotate MEASUREMENT switch to 3-LEVEL IMPULSE NOISE HITS & DROPOUTS.
   b. Depress C-MSG NOISE FILTER push-button.
   c. Depress BELL STD COUNT RATE push-button.
   d. Depress NON-STOP COUNT TIME push-button.
   e. Throw DISPLAY key to IMPULSE NOISE.
   f. Rotate IMPULSE NOISE LO THRESHOLD switch to 69 DBRN.
   g. Wait 30 seconds, then press START RESET push-button and verify that IN PROCESS annunciator is lit.
   h. Decrease IMPULSE NOISE LO THRESHOLD switch setting one dBrn at a time until COUNTS LO on left display start counting at a rate of at least one count per second. Verify that this setting is 62 to 66 dBrn.
   i. Continue to decrease IMPULSE NOISE LO THRESHOLD switch setting one dBrn at a time until COUNTS MID on center display start counting at a rate of at least one count per second. Verify that this setting is 3 to 5 dBrn below the setting in Step h.
   j. Continue to decrease IMPULSE NOISE LO THRESHOLD switch setting one dBrn at a time until COUNTS HI on right display start counting at a rate of at least one count per second. Verify that this setting is 7 to 9 dBrn below the setting in Step h.
   k. Verify that all counts accumulate by 1's.

NOTE

Although each display will be counting by 1s, they will not necessarily count at the same rate. It is not unusual to have different counts for COUNTS LO, COUNTS MID, and COUNTS HI.

   l. Depress CHNL LTD COUNT RATE push-button.
   m. Press START RESET push-button and verify that counts are now changing at a much greater rate than before.
   n. Throw DISPLAY key to HITS & DROPOUTS
   o. Rotate GAIN HIT THRESHOLD switch to 2 DB.
   p. Rotate PHASE HIT THRESHOLD switch to 15 DEGREES.
   q. Press START RESET push-button and verify that PHASE HITS and GAIN HITS accumulate by 2's and that DROPOUTS accumulate by 1's. A (—) sign should flash in the right display for every dropout that is counted.
   r. Rotate GAIN HIT THRESHOLD switch to 4 DB and verify that GAIN HITS stop being counted. Return GAIN HIT THRESHOLD switch to 2 DB.
   s. Rotate PHASE HIT THRESHOLD switch to 20 DEGREES and verify that PHASE HITS stop being counted. Return PHASE HIT THRESHOLD switch to 15 DEGREES.
   t. Depress BELL STD COUNT RATE push-button.
   u. Press START RESET push-button and verify that PHASE HITS, DROPOUTS, and GAIN HITS accumulate by 1's.

7. PHASE JITTER SELF CHECK:
   a. Rotate MEASUREMENT switch to PHASE JITTER.
   b. Verify a reading of 10.6 to 12.2 DEGREES on left display at the end of one minute.
   c. Verify a reading of 999 to 1009 RCV HZ on center display.
   d. Verify a reading of −1 to +1 DBM on right display.

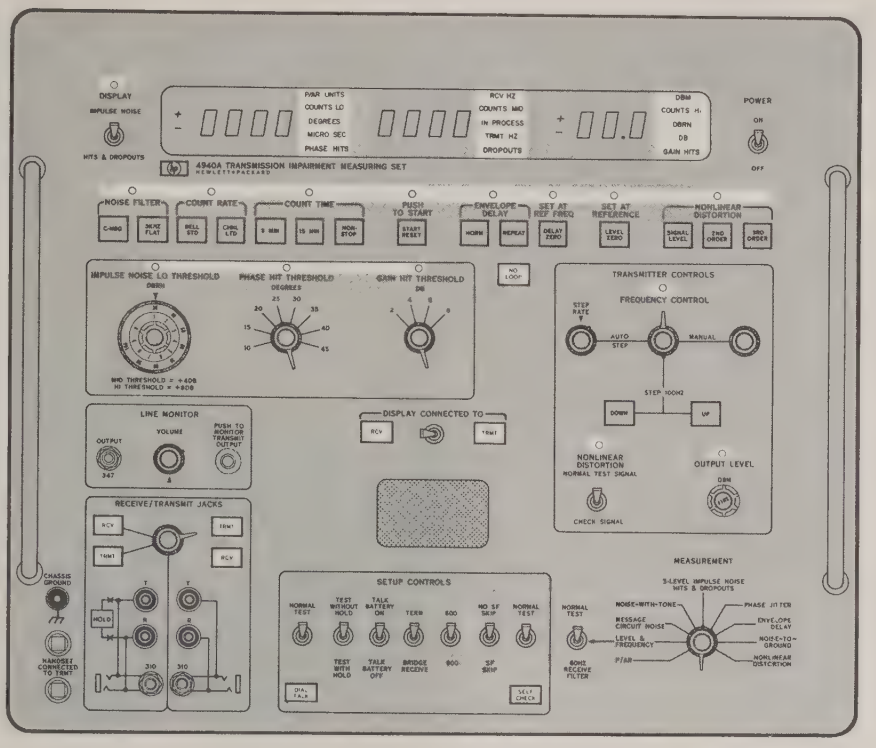
Figure 3-21. Self Check Procedures (Sheet 2 of 3)

8. ENVELOPE DELAY SELF CHECK:
   a. Rotate MEASUREMENT switch to ENVELOPE DELAY.
   b. Throw far right-hand SETUP CONTROLS key to NORMAL TEST.
   c. Depress NORM ENVELOPE DELAY push-button.
   d. Set frequency to 1004 TRMT HZ on center display by pressing STEP 100 HZ UP or DOWN push-buttons.
   e. Set OUTPUT LEVEL to 0 DBM on right display.
   f. Wait 15 seconds, then press DELAY ZERO push-button.
   g. Throw far right-hand SETUP CONTROLS key to SELF CHECK.
   h. Verify a reading of 2995 to 3005 MICRO SEC on left display at the end of 15 seconds.
   i. Verify a reading of −0.2 to +0.2 DBM on right display.
   j. Disconnect loop cord from TRANSMIT/RECEIVE JACKS. Verify that NO LOOP annunciator is lit, that all displays are blank, and that a ($\frac{-3}{-}$) sign appears in the right display. Reconnect loop cord.

9. NOISE-TO-GROUND SELF CHECK:
   a. Rotate MEASUREMENT switch to NOISE-TO-GROUND.
   b. Depress C-MSG NOISE FILTER push-button.
   c. Verify a reading of 83 to 85 DBRN on right display.

10. NONLINEAR DISTORTION SELF CHECK (Optional):
   a. Rotate MEASUREMENT switch to NONLINEAR DISTORTION.
   b. Depress SIGNAL LEVEL push-button.
   c. Verify a reading of −1 to +1 DBM on right display at the end of 15 seconds.
   d. Press LEVEL ZERO push-button.
   e. Verify a reading of −0 DB on right display.
   f. Depress 2ND ORDER push-button.
   g. Verify a reading of +6 to +8 DB on right display at the end of 15 seconds.
   h. Depress 3RD ORDER push-button.
   i. Verify a reading of +6 to +8 DB on right display at the end of 15 seconds.

Figure 3-21. Self Check Procedures (Sheet 3 of 3)



LAMP CHECKS AND REPLACEMENT

1. INDICATOR DOT LAMPS CHECK:
   a. Refer to MESSAGE CIRCUIT NOISE SELF CHECK.

NOTE

Replacement of indicator dot lamps requires special equipment and procedures and should be performed only by authorized repair shops.

2. DISPLAY ANNUNCIATOR LAMPS CHECK:
   a. Display annunciator lamps can be checked while performing SELF CHECK procedures.
   b. Verify that all display annunciator lamps illuminate evenly. Each annunciator employs two lamps for backup reliability; therefore, uneven illumination may indicate a burned out lamp.

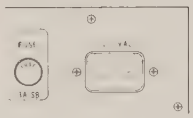
NOTE

Replacement of display annunciator lamps requires special equipment and procedures and should be performed only by authorized repair shops.

3. PANEL ANNUNCIATOR LAMPS CHECK:
   a. Rotate RECEIVE/TRANSMIT JACKS switch and verify that both sets of RCV and TRMT annunciator lamps light properly.
   b. Throw DISPLAY CONNECTED TO key between RCV and TRMT positions and verify that RCV and TRMT lamps light properly.
   c. Throw SETUP CONTROLS key to DIAL/TALK and verify that DIAL/TALK lamp lights properly.
   d. Throw SETUP CONTROLS key to SELF CHECK and verify that SELF CHECK lamp lights properly.
   e. Refer to ENVELOPE DELAY SELF CHECK to verify that NO LOOP lamp lights properly.

4. PANEL ANNUNCIATOR LAMPS REPLACEMENT:
   a. Switch POWER off.
   b. Insert fingernail in indentation at bottom of lens cap and pry up and out to remove lens cap.
   c. Gently grasp lamp base with needle-nose pliers and pull up and out to remove lamp.
   d. Insert new lamp with needle-nose pliers and replace lens cap. A spare lamp is located in the test set cover. In the rack mount versions, the spare lamp is located on the panel above the test set. Replace lamp with HP Part No. 2140-0405. (Oshino OL-685BPC, or equivalent).

Figure 3-22. Lamp Checks and Replacement

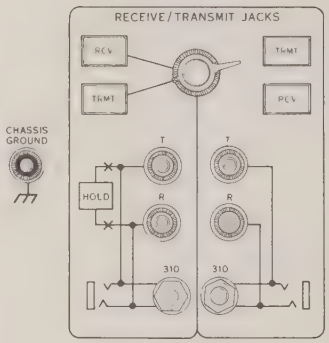


POWER CORD RECEPTACLE AND FUSE

117V AC (± 10%) 60Hz power is applied to the test set through the male power cord receptacle located on top of the test set. AC line fusing is provided by a 3 Amp (Slo Blo) fuse located in the fuse holder next to the power receptacle. A spare fuse is located in the test set cover. In the rack mount versions, the spare fuse is located on the panel above the test set.

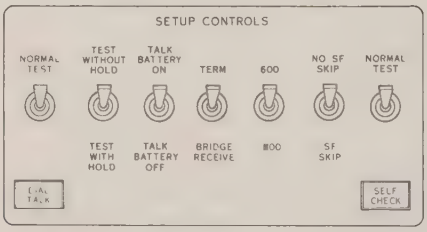
POWER SWITCH

POWER toggle switch turns the test set ON and OFF.



RECEIVE/TRANSMIT JACKS

A two position rotary switch is used to reverse the connections of the left and right jack fields. When the switch is in the up position, the left jacks are connected for RCV and the right jacks for TRMT. When the switch is in the down position, connections are reversed. Connections are indicated by the RCV and TRMT annunciators. Connections can be made either to the 310 jacks, or to the T (tip) and R (ring) binding posts, which are multipled. The left jack field should always be used for 2-wire wet transmit and receive connections; the right jack field for 2-wire dry connections. Both left and right jack fields are used for 4-wire connections. The CHASSIS GROUND binding post can be used to establish a ground reference if an adequate ground cannot be established through the 310 jack sleeves or power line plug.



SETUP CONTROLS

NORMAL TEST – DIAL/TALK

In NORMAL TEST mode the selected TRMT jack is connected to the test set's transmitter circuitry, but not to the lineman's handset posts. In DIAL/TALK mode the TRMT jack is connected to the lineman's handset posts, but not to the transmitter circuitry.

TEST WITHOUT HOLD – TEST WITH HOLD

In TEST WITHOUT HOLD mode the test set holding circuit is disconnected from the RECEIVE/TRANSMIT JACKS. In TEST WITH HOLD mode the holding circuit is connected across tip and ring of the left jack field to hold 2-wire wet (DDD) circuits while testing.

TALK BATTERY ON – TALK BATTERY OFF

In TALK BATTERY ON mode the test set provides the necessary talk battery to the lineman's handset to talk on dry circuits. In TALK BATTERY OFF mode, talk battery must be supplied by the circuit under test if talking is desired.

TERM – BRIDGE RECEIVE

In TERM mode the test set provides a termination on both the RCV and TRMT circuits. The desired terminating impedance must be selected with the 600/900 key. In BRIDGE RECEIVE mode the receiving test set is bridged across the line under test, which is terminated with another device.

NOTE

When using the BRIDGE RECEIVE mode it is still necessary to select the impedance of the line under test with the 600/900 key in order to normalize the measurements.

Figure 3-23. Description of Controls, Connectors, and Indicators (Sheet 1 of 6)

600 – 900

The 600Ω or 900Ω mode must be selected to match the characteristic impedance of the line under test. When operating in the TERM mode, both the TRMT and RCV lines are terminated in the selected impedance. When operating in the BRIDGE RECEIVE mode, the TRMT line is terminated in the selected impedance and the RCV line is bridged by more than 50kΩ. The selection also normalizes level measurements for the respective impedances.

NO SF SKIP – SF SKIP

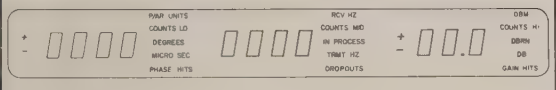
In NO SF SKIP mode the test set will transmit all selected frequencies. In SF SKIP mode the test set will not transmit any frequencies between 2450Hz and 2750Hz. This is to prevent the circuit under test from being disconnected by SF signaling units in the dial-up network.

NORMAL TEST – SELF CHECK

In NORMAL TEST mode the test set performs normal testing. In SELF CHECK mode proper operation of the test set can be verified by making measurements on its built-in self check circuitry.

HANDSET CONNECTED TO TRMT POSTS

Two "cuff-link" posts provide the connection terminals for a lineman's handset (butt-in). The terminals are connected to the selected TRMT jack when the DIAL/TALK mode is selected.

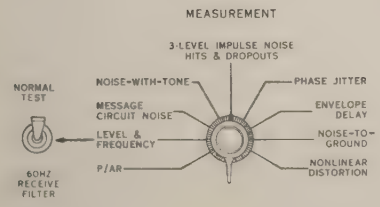


DIGITAL DISPLAYS

Three digital displays provide measurement units and quantitative information for all measurements. Ranging is automatic, and polarity and decimal points are automatically displayed when appropriate. Up to three parameters can be displayed simultaneously. The displays also indicate underrange and overrange conditions. Display of only a (–) sign indicates underrange. Display of only a (+) sign indicates overrange.

DISPLAY CONNECTED TO KEY

The digital displays will present either the transmitted or received quantities when the DISPLAY CONNECTED TO key is thrown to TRMT or RCV, respectively.



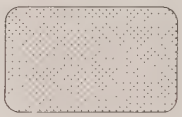
MEASUREMENT SWITCH

The MEASUREMENT switch programs the test set to perform the selected measurement. The MEASUREMENT switch sets up indicator dot lamps, guiding the operator to other controls which need to be selected. Adjacent to the LEVEL & FREQUENCY position is the NORMAL TEST/60 Hz RECEIVE FILTER key. When the spring return key is held down in the 60 Hz RECEIVE FILTER position, a high pass filter attenuates 60 Hz power hum on the received signal. This filter reduces level measurement error caused by power line related noise. The filter is disconnected in the NORMAL TEST position.

NOTE

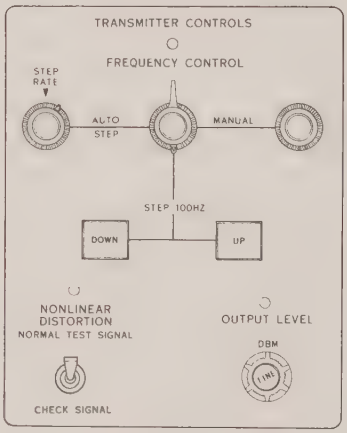
P/AR and NONLINEAR DISTORTION measurements are optional features and may not appear on some configurations of the test set.

Figure 3-23. Description of Controls, Connectors, and Indicators (Sheet 2 of 6)



LINE MONITOR

The LINE MONITOR permits listening to the line under test, or the test set transmitter, on the built-in speaker or an external headset. The LINE MONITOR is normally connected to the receive line. To monitor the transmit line, press the PUSH TO MONITOR TRANSMIT OUTPUT push-button. When a plug is inserted in the 347 OUTPUT jack, the speaker is disconnected and the amplifier drives a headset or other device connected (must have an impedance of 150Ω or greater). An oscilloscope, spectrum analyzer, or other measuring device can also be connected to the LINE MONITOR OUTPUT for further analysis of the line under test. The output is an amplified reproduction of signals on the line (except in noise measurements, where the output amplitude is weighted by the selected NOISE FILTER).



TRANSMITTER CONTROLS

FREQUENCY CONTROL SWITCH

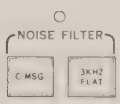
The FREQUENCY CONTROL switch is a three position rotary switch which selects the transmitter frequency control mode. In AUTO STEP mode the frequency is automatically stepped in 100Hz increments from 204Hz to 3904Hz at a rate controlled by the STEP RATE control. Frequencies are stepped repetitively up and down between the two limits, beginning at the point where the transmitter frequency is initially set. In STEP 100 HZ mode the frequency is manually stepped in 100Hz increments from 204Hz to 3904Hz by pressing the UP or DOWN push-buttons. (The STEP 100 HZ UP or DOWN push-buttons are also active in the AUTO STEP mode and can be used to override automatic stepping.) In MANUAL mode frequency is continuously variable over the range of 200Hz to 3904Hz by adjusting the MANUAL control.

OUTPUT LEVEL CONTROL

The OUTPUT LEVEL control varies the output continuously over the range of −49dBm to +10dBm (to 0dBm for P/AR and NONLINEAR DISTORTION). Output level is adjusted while observing DBM on the right display.

NONLINEAR DISTORTION KEY

(This control is present only on test sets with the NONLINEAR DISTORTION option.) The NONLINEAR DISTORTION key permits comparison of a normal test signal and a check signal so that compensation for background noise can be made. When the key is in the NORMAL TEST SIGNAL position, two pairs of tones, centered at 860Hz and 1380Hz, are transmitted. When the spring return key is held in the CHECK SIGNAL position, power of the 860Hz tones is doubled and the 1380Hz tones are turned off.



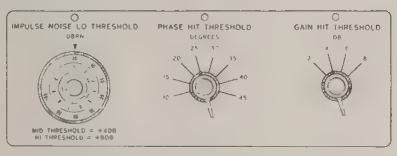
NOISE FILTER PUSH-BUTTONS

The NOISE FILTER push-buttons allow selection of either C-MSG or 3 KHZ FLAT noise weighting filters. Depressing a push-button activates the selected filter.

DISPLAY KEY

The DISPLAY key is used in conjunction with 3-LEVEL IMPULSE NOISE HITS & DROPOUTS measurements. When the key is thrown to IMPULSE NOISE position the displays will show COUNTS LO, COUNTS MID, and COUNTS HI. When the key is thrown to HITS & DROPOUTS position the displays will show PHASE HITS, DROPOUTS, and GAIN HITS. The three parameters not being exhibited are stored in the test set memory until they are recalled by the DISPLAY key. The key can also be operated while the measurements are in process to monitor a desired count accumulation.

Figure 3-23. Description of Controls, Connectors, and Indicators (Sheet 3 of 6)



IMPULSE NOISE LO THRESHOLD SELECTOR

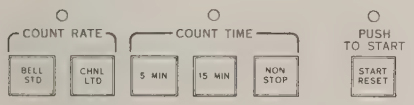
The IMPULSE NOISE LO THRESHOLD selector is a two level concentric rotary switch which sets the desired lower "window" for impulse noise counts. The setting, in dBrn, is the total of the outer ring (tens) and the inner ring (units) alignment at the index mark. The test set will totalize as COUNTS LO, impulses whose peaks are above the selected threshold. The MID THRESHOLD is fixed at 4dB above the LO THRESHOLD setting. The test set will totalize as COUNTS MID, impulses whose peaks are above the MID THRESHOLD. The HI THRESHOLD is fixed at 8dB above the LO THRESHOLD setting. The test set will totalize as COUNTS HI, impulses whose peaks are above the HI THRESHOLD.

PHASE HIT THRESHOLD SWITCH

The PHASE HIT THRESHOLD switch selects the desired threshold for phase hit counts. The test set will totalize as PHASE HITS, rapid changes of phase that exceed the switch setting.

GAIN HIT THRESHOLD SWITCH

The GAIN HIT THRESHOLD switch selects the desired threshold for gain hit counts. The test set will totalize as GAIN HITS, rapid changes of gain that exceed the switch setting.



COUNT RATE PUSH-BUTTONS

The COUNT RATE push-buttons are used in conjunction with 3-LEVEL IMPULSE NOISE HITS & DROPOUTS measurements. When the BELL STD push-button is depressed the maximum rate at which counts can be totalized is limited to seven counts per second (per Bell Tariff). When the CHNL LTD push-button is depressed the maximum rate at which counts can be totalized is limited only by the channel bandwidth and the selected NOISE FILTER in the test set.

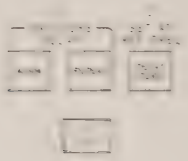
COUNT TIME PUSH-BUTTONS

The COUNT TIME push-buttons are used in conjunction with 3-LEVEL IMPULSE NOISE HITS & DROPOUTS measurements. When the 5 MIN push-button is depressed, the test set will totalize counts for 5 minutes from the time the START RESET push-button is pressed. Likewise, the 15 MIN push-button will provide a 15 minute counting interval. The IN PROCESS annunciator will light up during the counting interval and will extinguish when the interval is completed. When the NON-STOP push-button is depressed, the test set will totalize counts indefinitely from the time the START RESET push-button is pressed. The count time will cease and the displays reset to zero when another COUNT TIME push-button is depressed; when the START RESET push-button is pressed; when the MEASUREMENT switch is rotated; or when POWER is switched off.

START RESET PUSH-BUTTON

The START RESET push-button is used in conjunction with 3-LEVEL IMPULSE NOISE HITS & DROPOUTS measurements. When pressed, the push-button clears the displays of their previous counts and initiates a new count period.

Figure 3-23. Description of Controls, Connectors, and Indicators (Sheet 4 of 6)



ENVELOPE DELAY PUSH-BUTTONS

The ENVELOPE DELAY NORM and REPEAT push-buttons determine whether the test set will be used to measure envelope delay (NORM) or to re-transmit the envelope delay signal from the far-end of the circuit (REPEAT).

DELAY ZERO PUSH-BUTTON

The DELAY ZERO push-button is used in conjunction with ENVELOPE DELAY measurements. When the normal test set is adjusted to the desired reference frequency, pressing the DELAY ZERO push-button will establish a zero microsecond delay reference. All subsequent envelope delay measurements are relative to this reference point.

NO LOOP ANNUNCIATOR

The NO LOOP annunciator will light up if the envelope delay loop is broken, or if the channel is attenuating either the transmit or receive signal to the extent that accurate readings cannot be made.

LEVEL ZERO PUSH-BUTTON

The LEVEL ZERO push-button is used in conjunction with LEVEL & FREQUENCY; and NONLINEAR DISTORTION measurements. When the test set is adjusted to the desired reference frequency, pressing the LEVEL ZERO push-button will establish a zero dB reference. All subsequent measurements will be made in dB relative to this reference point. If this push-button is not pressed, measurements will be in absolute dBm.

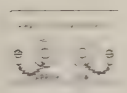
NOTE

If LEVEL ZERO push-button is pressed and it is desired to make an absolute dBm measurement, momentarily rotate the MEASUREMENT switch out of the selected mode, then back again.

NONLINEAR DISTORTION PUSH-BUTTONS

(These push-buttons are present only on test sets with the NONLINEAR DISTORTION option.) The SIGNAL LEVEL push-button allows measurement of the total received level of the nonlinear distortion test signal. Depressing the 2ND ORDER push-button allows measurement of only second order distortion products. Likewise, depressing the 3RD ORDER push-button allows measurement of only third order distortion products.

Figure 3-23. Description of Controls, Connectors, and Indicators (Sheet 5 of 6)



PHASE JITTER OUTPUT CONNECTORS

CARRIER

The CARRIER output provides a square wave output signal whose frequency is equal to the received carrier frequency. The CARRIER output may be used to synchronize an oscilloscope to measure phase jitter of the received signal as accessed through the LINE MONITOR-OUTPUT. The signal level is TTL derived, with a nominal 10 k-ohms source impedance. The square wave signal is derived from the Phase Jitter VCO or Frequency Tracking VCO, dependent on the MEASUREMENT switch position. The VCO will track a received signal over the frequency range specified for the receiver in that MEASUREMENT switch position.

PM (Phase Modulation)

The PM output provides an output proportional to the instantaneous phase deviation of the received signal when the MEASUREMENT switch is in the PHASE JITTER position. The PM output may be used for phase jitter spectral analysis. The table below provides the performance characteristics of this output.

PM OUTPUT PERFORMANCE CHARACTERISTICS

Source Impedance: Nominal 10 k-ohms
Phase Response: 0-60° nominal
Bandwidth: 20 Hz - 300 Hz
Sensitivity: 0.1 volts peak-to-peak/degree ± 10%

Figure 3-23. Description of Controls, Connectors, and Indicators (Sheet 6 of 6)

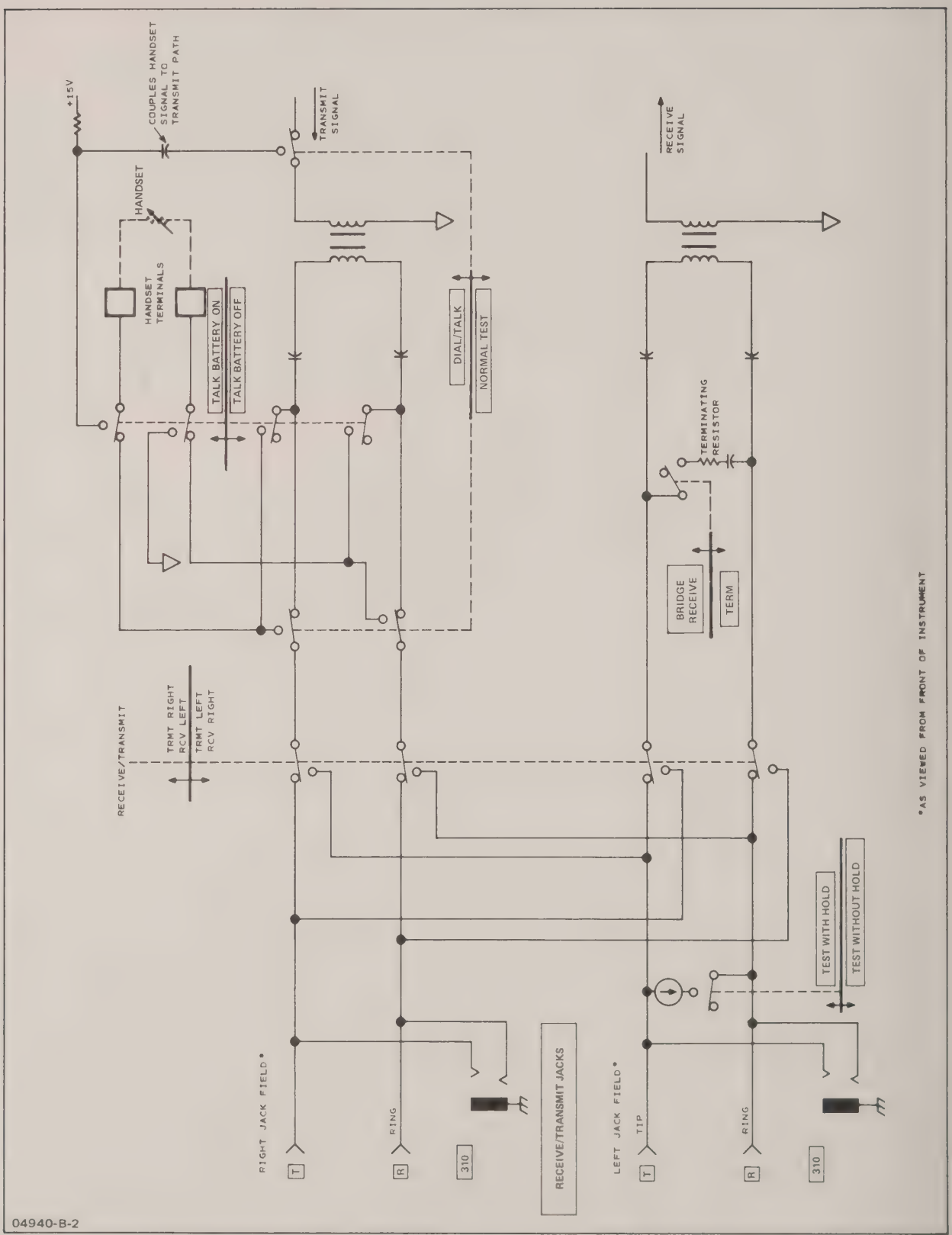


Figure 4-1. Input-Output Switching

MEASUREMENT PRINCIPLES

SECTION IV

4-1. INTRODUCTION.

4-2. This section describes the principles of all measurements made by the Transmission Impairment Measuring Set (TIMS). Included are explanations of the need for the measurements, plus the effect of certain voice channel parameters on data transmission. Block diagrams and functional descriptions are provided to explain the TIMS input-output switching and the different measurements which the test set will make.

4-3. For further information concerning the voice channel measurements described in this section, refer to the following Bell System Technical References: PUB 41008, *Analog Parameters Affecting Voiceband Data Transmission — Description of Parameters,* and PUB 41009, *Transmission Parameters Affecting Voiceband Data Transmission — Measuring Techniques.* These publications are available from Supervisor — Information Distribution Center, American Telephone and Telegraph Co., 195 Broadway, Room 208, New York, N.Y. 10007.

4-4. INPUT-OUTPUT SWITCHING.

4-5. The RECEIVE/TRANSMIT JACKS provide for interconnection of TIMS to the circuit under test. See figure 4-1. The RECEIVE/TRANSMIT switch provides for selection of either the transmit or receive function for the left jack field, and simultaneously selects the opposite for the right jack field. Both the left and right jack fields provide parallel (multipled) connection jacks: standard five-way binding posts on top and Western Electric 310 type jacks on the bottom. Either the binding posts or the 310 jacks may be used; both of them will not normally be used at the same time.

4-6. If a 2-wire wet (direct distance dialing — DDD) circuit is under test, the left jack field will normally be used to allow application of the 21 mA current source, for latching of telephone switching equipment (TEST WITH HOLD). Either the left or right jack field may be used for a 2-wire dry circuit (data access arrangement — DAA). If a 4-wire circuit (dedicated data circuit) is under test, the left jack field may be used for either transmit or receive, and the right field the opposite.

4-7. The input and output impedance of TIMS is selectable at either 600 or 900 ohms (not shown in figure 4-1), which are standard telephone circuit values. The impedance of the test set must be selected to match the circuit under test, or erroneous measurement values will be obtained.

4-8. The receive input may be terminated or bridged across the circuit under test. The terminated mode provides a resistive termination on the receive circuit to provide proper loading. When a termination is provided by some other device, then it is not necessary (nor desirable) to provide a termination. In this case the receive input should be used in the bridged mode, which provides a high impedance receive input (greater than 50 k-ohms).

4-9. The TIMS input and output circuits are balanced to match standard telephone voice channel lines. A balanced line is one that is electrically symmetrical; the two sides of the line have equal series resistance, series inductance, shunt capacitance, and leakage to ground. Only test sets (or other devices) with balanced inputs and outputs will operate properly when connected to a balanced line. If it is desired to use some device with an unbalanced input (for instance an oscilloscope or spectrum analyzer) to monitor the signal on the balanced line, then the device can be connected to the LINE MONITOR OUTPUT. This output is an unbalanced, amplified reproduction of the signal on the line (except in noise measurements, where the output amplitude is weighted by the selected NOISE FILTER).

4-10. To allow dialing, talking, and listening over the circuit under test, handset terminals (or "cuff links") are provided for the connection of a lineman's handset. In addition, talk battery is selectable for use on dry circuits (circuits which do not incorporate a power source to provide direct current flow for talking).

4-11. DATA LEVEL.

4-12. Transmission measurements on data circuits use test signals applied at data level (the standard Bell System data level is -13 dBmO). Data level is used to prevent overload on carrier systems. Data level is a power 13 dB below the transmission level point (TLP) where the tests are being made. For example, at a -16 dB TLP, the data level would be -29 dBm (-16 -13 = -29). A test power of -29 dBm would be applied here. At the zero transmission level point (O TLP), the data level would be -13 dBm, or -13 dBmO.

4-13. LEVEL AND FREQUENCY MEASUREMENTS.

4-14. The level and frequency mode allows measurement

of 1000 Hz loss and attenuation distortion. These measurements define the amplitude versus frequency response of a voice channel. The level and frequency mode also allows measurement of frequency shift. Figure 4-2 illustrates the basic setup for these measurements.

4-15. 1000 Hz LOSS.

4-16. The 1000 Hz loss measurement determines the point-to-point loss (or gain) of a 1000 Hz test tone transmitted over a voice channel. To make this measurement, a 1004 Hz test frequency is transmitted at data level. At the receiving TIMS, the received power is measured (in dBm) and subtracted from the transmitted level to determine 1000 Hz loss.

4-17. The transmitted frequency is actually 1004 Hz (not 1000 Hz), to prevent measurement errors which would occur over T-carrier systems. The test set offsets all stepped transmitter frequencies by 4 Hz. This offset avoids measurement error caused by test frequencies which are submultiples of the T-carrier sampling rate. This measurement error is not representative of actual conditions which are present when multifrequency signals like voice and data are transmitted over voice channels.

4-18. The accuracy of the received power measurement depends on the tolerance of the receiving end resistive termination. A terminating resistance of ±1% tolerance (at 600 or 900 ohms) is required to assure accurate measurements. Therefore, received level measurements should generally be made using the TIMS internal termination; either 600 or 900 ohms, as appropriate.

4-19. A switch-selectable 60 Hz high-pass receiving filter is provided for use with the level and frequency measurements. The 60 Hz filter is used to detect and/or remove excessive 60 Hz interference. The filter has a 25 dB attenuation characteristic at 60 Hz, and a 4 dB attenuation characteristic at 180 Hz (3rd harmonic of 60 Hz).

4-20. FREQUENCY SHIFT.

4-21. The frequency shift measurement checks for any difference in the received frequency with reference to the transmitted frequency (frequency translation) as caused by carrier facilities. To make this measurement, a test tone of known frequency is transmitted. At the receiving end, the received frequency is observed and compared with the transmitted frequency. Any difference between transmitted and received frequencies indicates a frequency shift in the test signal. This measurement is not valid when measured on looped around carrier facilities, since the frequency shift in one direction (near-end to far-end) may be cancelled by the frequency shift in the other direction (far-end to near-end).

4-22. ATTENUATION DISTORTION.

4-23. The attenuation distortion measurement determines the amplitude versus frequency characteristics of a voice channel; using a single frequency measurement technique. This measurement determines the usable bandwidth of the voice channel. To make this measurement, a 1004 Hz test frequency is transmitted at data level. At the receiving end, the received power is recorded to obtain a 1004 Hz reference level. The transmitted frequency is then varied over the full range of the voice channel (while maintaining data level), and the received power is noted in each case. The received powers may then be compared to the 1004 Hz received reference power to obtain the frequency attenuation characteristics of the voice channel in dBm.

4-24. To directly obtain the loss deviations relative to 1004 Hz, the LEVEL ZERO pushbutton is depressed during reception of the 1004 Hz reference signal. This action stores the received power in dBm and simultaneously displays this level as 0 dB. Level readings taken at other frequencies will then be displayed in units of dB as compared to the 1004 Hz reference. This eliminates the need to subtract the 1004 Hz reference level from other levels at other frequencies to obtain dB indications.

4-25. According to telephone industry convention, attenuation distortion is defined as a change in loss of a channel, compared to the loss of a nominal 1000 Hz signal on that channel. For example, a channel with 6 dB more loss at 2800 Hz would have an attenuation distortion of +6 dB.

4-26. The SF (single-frequency) skip setup switch is provided to automatically prevent the test set from transmitting frequencies within the range of 2450 Hz to 2750 Hz. This feature is used in attenuation distortion and envelope delay to prevent loss of voice channel connection when transmitting over a dial-up network incorporating SF signaling units.

4-27. MESSAGE CIRCUIT NOISE MEASUREMENTS.

4-28. The message circuit noise measurements attempt to determine the interfering effects of background noise and tones. Figure 4-3 illustrates the basic setup for these measurements.

4-29. The message circuit noise mode measures the noise present on a voice channel, which has a quiet termination on one end (supplied by transmitting TIMS) and a weighted

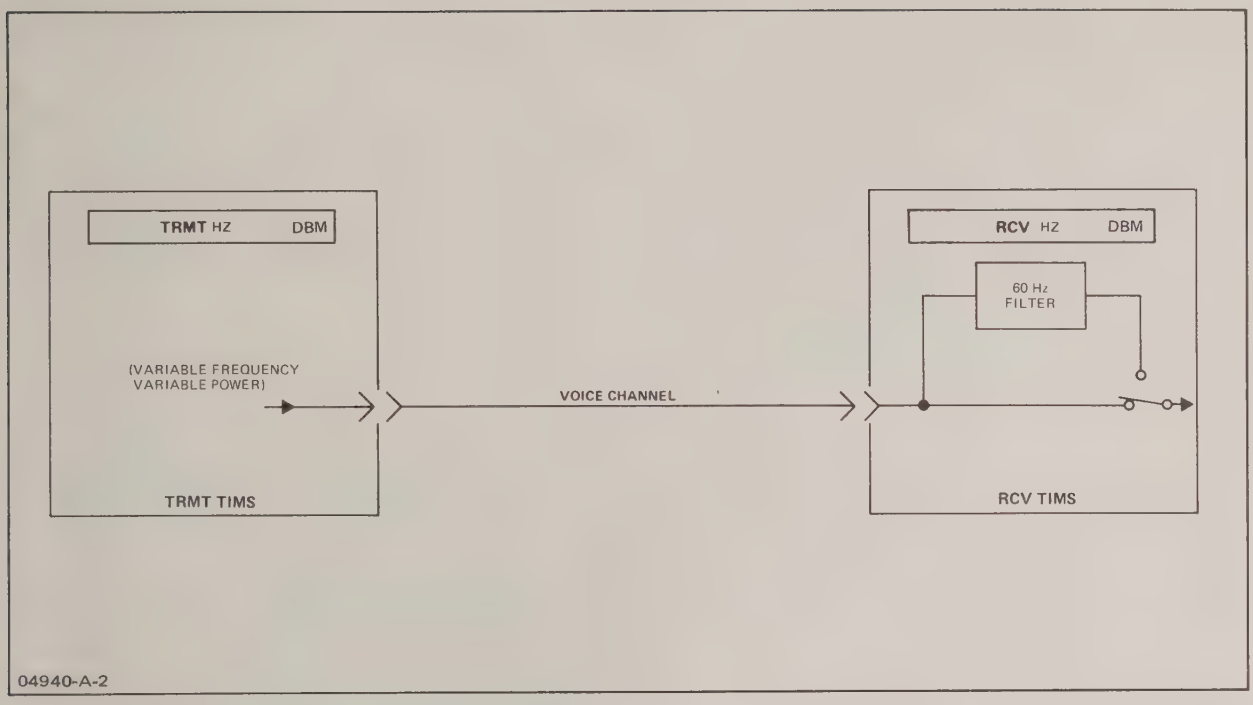


Figure 4-2. Level and Frequency Measurements

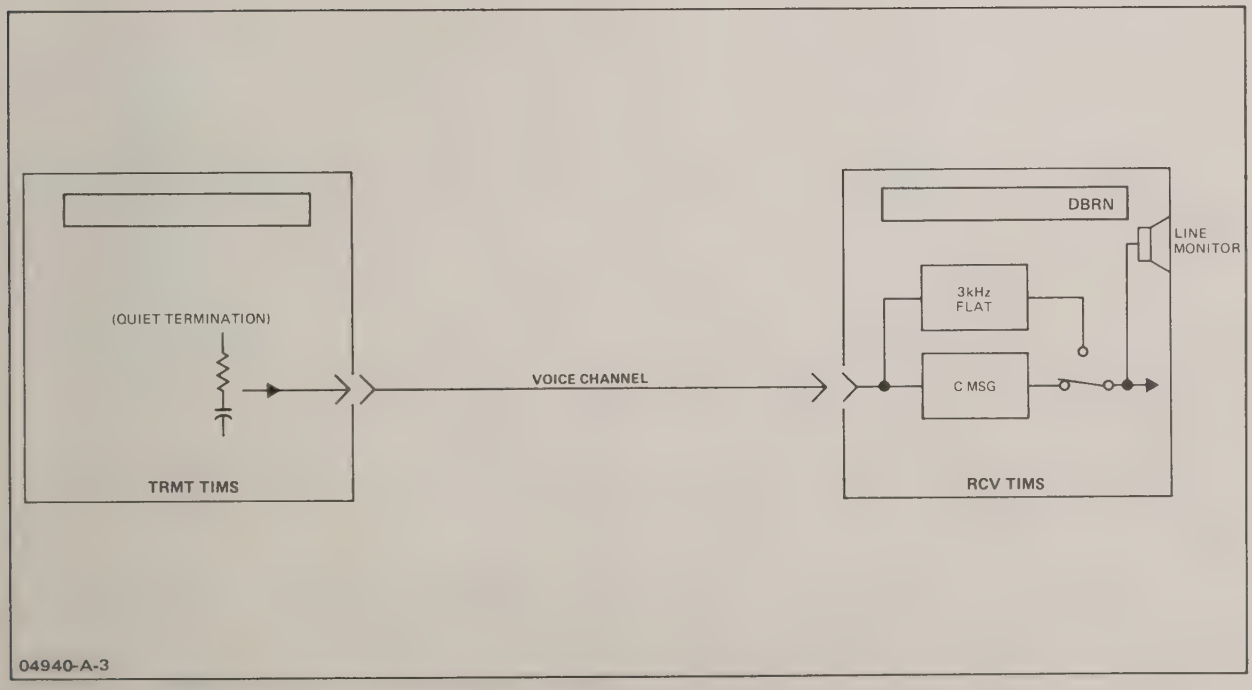


Figure 4-3. Message Circuit Noise Measurements

measuring device on the other end (receiving TIMS). The quiet termination is a simple resistive termination on the wire pair.

4-30. At the measurement end of the voice channel, TIMS includes a frequency weighting filter, either C-message or 3 kHz flat (see figures 4-4 and 4-5). The C-message filter allows measurement of only those noise signals that are of annoyance to the "typical" subscriber of standard telephone service. The C-message weighting is also used to evaluate the effects of noise on voice-grade data circuits. The C-weighting is valid for data transmission since the response characteristic is relatively flat over most of the frequency range of concern for data transmission (600 to 3000 Hz).

4-31. The 3 kHz flat filter has a response that provides much less attenuation to the low frequencies (60 Hz to 500 Hz) than the C-message filter. By comparing a 3 kHz flat noise measurement to a C-message noise measurement, the relative influence of low frequency noise (60 Hz commercial power, 20 Hz ringing, etc.) can be determined.

4-32. Received noise levels are displayed in units of dBrn, or dB with respect to reference noise (1000 Hz tone at -90 dBm). For example, a noise reading of 20 dBrn has an RMS power of -70 dBm (20 - 90 = -70). With the C-message filter selected, displayed readings are interpreted as being in units of dBrnC, or noise level in dBrn with a C-message weighted measuring device.

4-33. SINGLE FREQUENCY INTERFERENCE.

4-34. Single frequency interference refers to unwanted steady tones which may appear on voice channels. Occasional bursts of low level tones which may occur from crosstalk of multifrequency signaling, for example, do not fall in this category. Single frequency tones may interfere with certain data signals, particularly narrowband signals which are multiplexed onto a voiceband channel.

4-35. A simple audio monitoring arrangement will usually detect this interference, since tones exceeding acceptable levels are easily heard if the C-message noise is within limits. The single frequency interference check is made with the setup shown in figure 4-3. After the received noise signal passes through the C-message filter, the resultant signal is applied to the line monitor speaker. The TIMS operator listens for any predominant tone, which may indicate a single frequency interference problem.

4-36. If a single frequency tone (or tones) of long duration is heard, single frequency interference may be present and should be measured. To precisely determine the frequency and level of the interfering tone, a frequency selective voltmeter or spectrum analyzer must be used. The requirement for single frequency interference is that, when measured through a C-message filter, it be at least 3 dB below C-message noise limits.

4-37. NOISE-WITH-TONE MEASUREMENTS.

4-38. The noise-with-tone mode allows measurement of signal-to-noise ratio, which is one of the most important parameters for determining the quality of a voice channel.

4-39. NOISE-WITH-TONE.

4-40. The noise-with-tone measurement technique is used to condition compandors and/or quantizers in the transmission system to their normal operating levels for continuous data signals. Therefore, noise levels are recieved which duplicate levels present under operating conditions.

4-41. To make this measurement, a 1004 Hz test frequency (holding tone) is transmitted at data level. At the receiving TIMS, the 1004 Hz holding tone is selectively attenuated by 50 dB using a notch filter (all frequencies between 995 Hz and 1025 Hz are attenuated by 50 dB). The remaining received signal(noise) is passed through either a C-message or 3 kHz flat filter for measurement. The received noise level is displayed in units of dBrn. Figure 4-6 illustrates the combination of the C-message weighting and notch filter characteristics.

4-42. SIGNAL-TO-NOISE RATIO.

4-43. The signal-to-noise ratio of the voice channel under test may be determined by comparing the noise-with-tone level (C-message weighted) with the holding tone level. To determine signal-to-noise ratio, the noise level (dBrn) is noted after measurement as explained above. The receiving TIMS is then switched to the message circuit noise measurement mode. This action removes the notch filter from the receiving TIMS (retains C-message filter). Since the received holding tone level is normally much greater than the received noise level, the holding tone level is indicated on the TIMS display in units of dBrn. The signal-to-noise ratio (units of dB) is then obtained by subtracting the noise level from the holding tone level. For example, if the received holding tone level is measured as 70 dBrn and the noise level is measured at 50 dBrn, the signal-to-noise ratio equals 20 dB (70 - 50 = 20).

4-44. IMPULSE NOISE, HITS AND DROPOUTS MEASUREMENTS.

4-45. The 3-level impulse noise, hits and dropouts mode measures the interfering effects of transient phenomena.

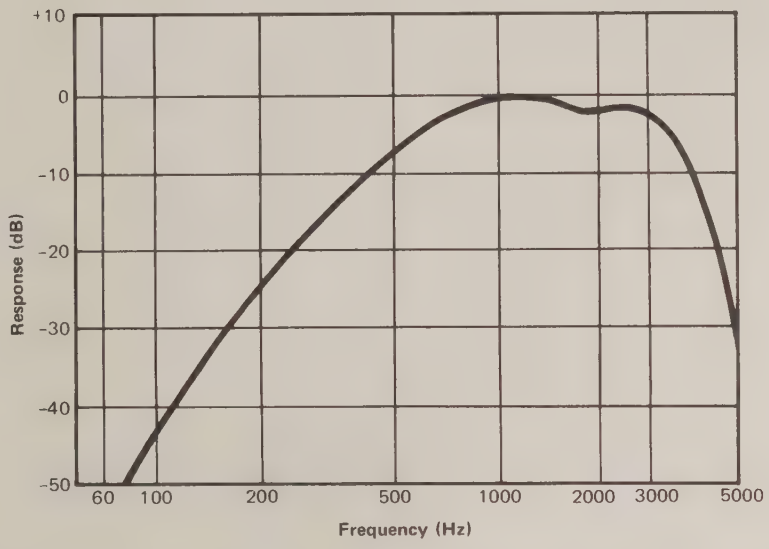


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Figure 4-4. C-Message Weighting Characteristic

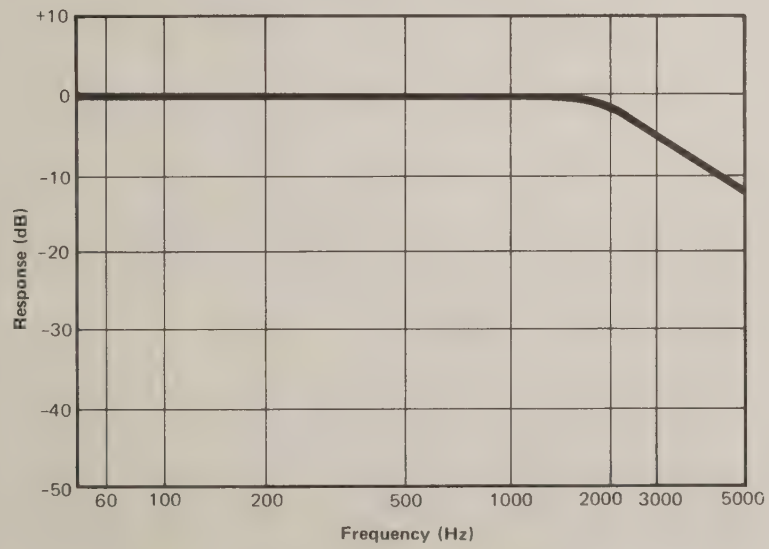

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Figure 4-5. 3 kHz Flat Weighting Characteristic

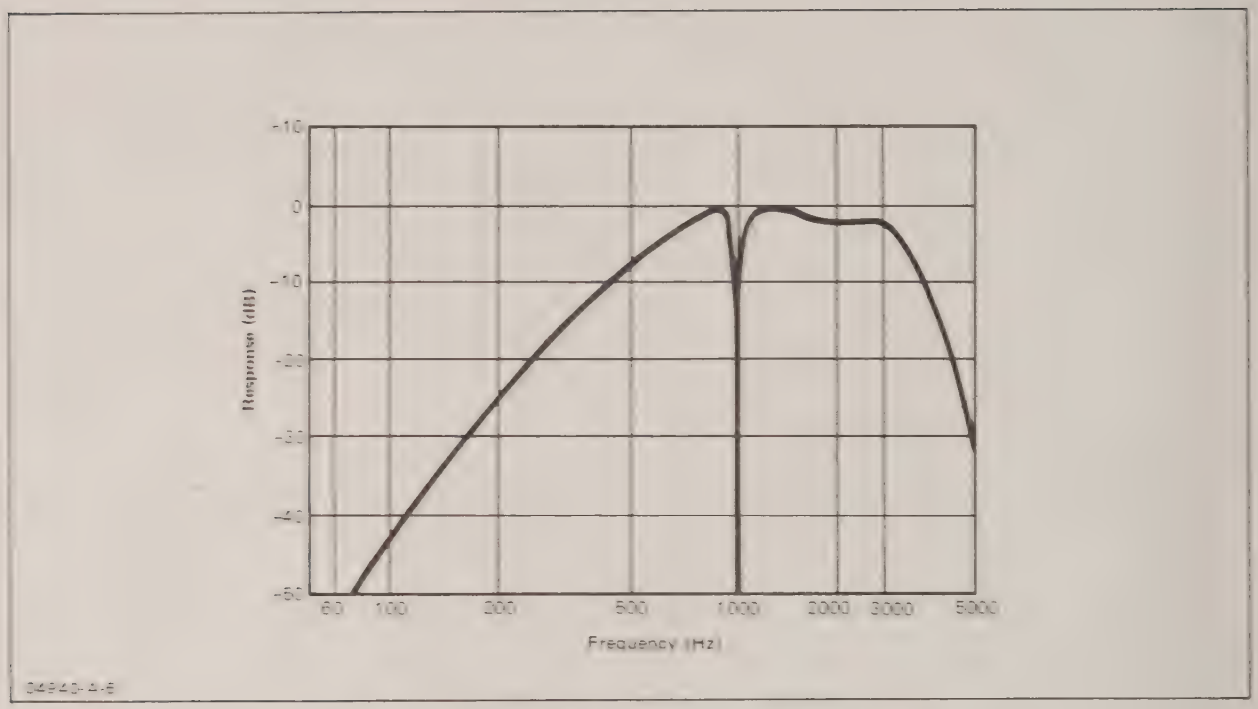


Figure 4-6. C-Message Weighting with Notch Characteristic

These transient phenomena can cause data transmission errors and/or interruptions to data communication systems. This measurement mode allows simultaneous determination of: impulse noise count at three different thresholds, phase hit count, gain hit count, and dropout count. The simultaneous measurement of these transient phenomena allows TIMS to reliably differentiate between each of them.

4-46. IMPULSE NOISE.

4-47. Impulse noise is that component of the received noise signal which is much greater in amplitude than the normal peaks of the message circuit noise, and that occurs as short duration spikes and/or bursts of energy. Studies by Bell Telephone laboratories have shown that impluse noise spikes have a duration of less than one millisecond, and that all significant effects of the noise spike disappear within four milliseconds. Waveform (b) in figure 4-7 illustrates a received holding tone (or test signal) that includes interfering impulse noise spikes. The impluse noise measurement allows determination of impulse noise count on a voice channel, given a specified amplitude threshold level, a specified count rate, and a specified measurement period (all switch selectable on TIMS).

4-48. Most impulse noise originates with actions of people. Customers initiating and terminating calls cause relays and switches to operate and release, giving rise to impulse noise from the associated electrical transients. Normal installation and repair activities also introduce impulse noise.

4-49. Impulse noise affects data transmission by causing the loss of the information signal which results in errors. In slow data rate systems, few errors occur due to impulse noise because it is easy for the receiving device to distinguish a data pulse from an impulse noise pulse. As the data rate of a system increases, it becomes increasingly difficult for the receiving device to distinguish the data pulse from the noise pulse; resulting in impulse noise caused errors.

4-50. PHASE HITS, GAIN HITS, AND DROPOUTS.

4-51. PHASE HITS. A phase hit is a sudden change (+ or -) in the received signal phase (or frequency). Phase hits may be as small as tenths of a degree (treated as phase jitter — discussed in later paragraphs) or as large as 360°. The phase of the received signal may return to its original value in a short time, or remain indefinitely at a changed value. Waveform (c) in figure 4-7 illustrates a received holding tone that includes interfering phase hits.

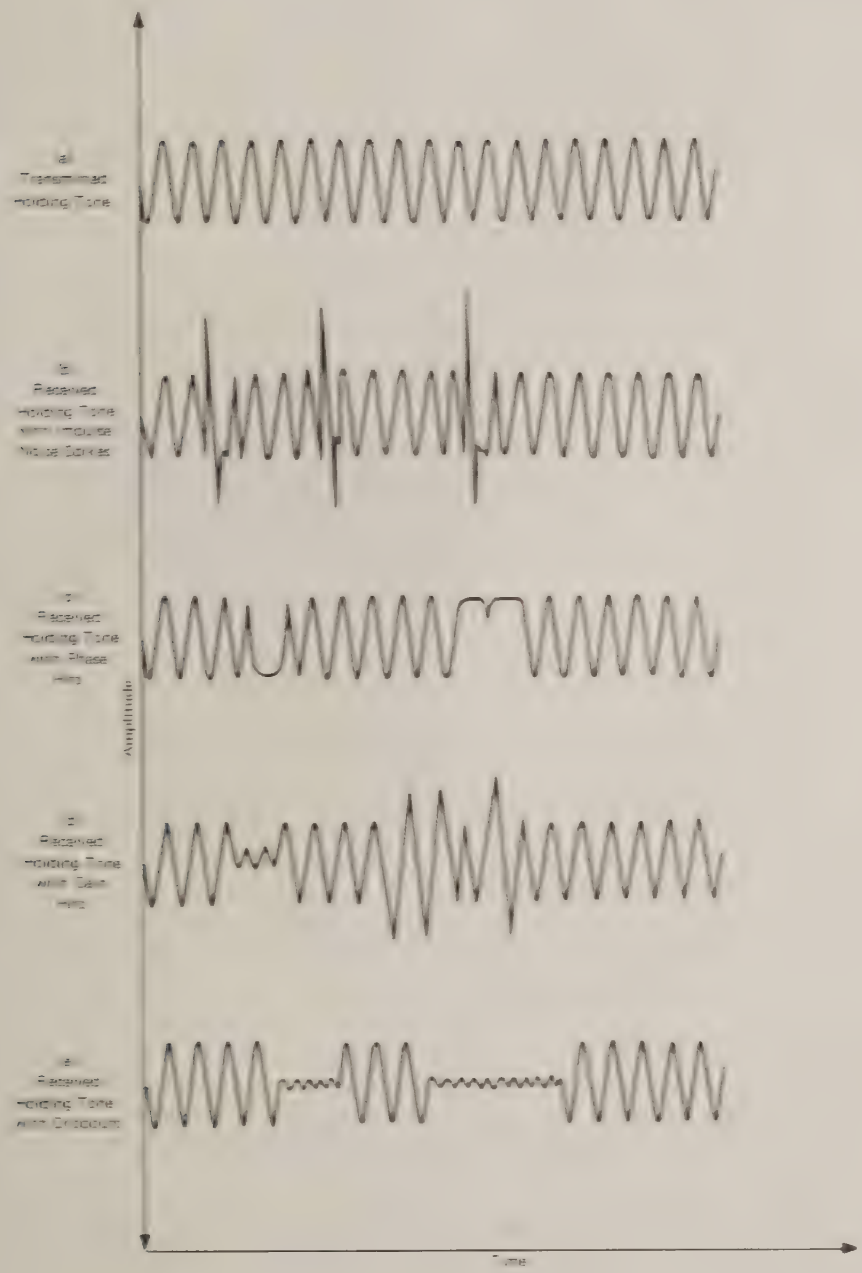


Figure 4-7. Impulse Noise, Hits and Dropouts Waveforms

4-52. Some of the more common causes of phase hits (and also gain hits and dropouts discussed below) are automatic switching to standby facilities or carrier supplies, patching out working facilities to perform routine maintenance, fades or path changes in microwave facilities, and noise transients coupled into carrier frequency sources.

4-53. Since two common modulation techniques used by data modems for transmission are phase and frequency modulation, phase hits create errors by appearing like the information carried by the data signal. For example, in a system using an 8-phase modulation technique (45° between states), frequent 25° phase hits would make it very difficult for the receiving modem to distinguish between the interfering phase hits and the phase modulation; resulting in phase hit caused errors.

4-54. GAIN HITS. A gain hit is a sudden change (increase or decrease) in the received signal level. Gain hits may be as small as tenths of a dB or as large as tens of dBs. The level of the received signal may return to its original value in a short time, or remain indefinitely at a changed value. Waveform (d) in figure 4-7 illustrates a received holding tone that includes interfering gain hits.

4-55. Amplitude modulation of a carrier signal is another common technique used by modems to transmit data. Since the information is contained in the level of the signal, gain hits can appear like the information carried by the data signal; resulting in gain hit caused errors.

4-56. DROPOUTS. A dropout is a sudden drop in received signal level. During a dropout, the signal experiences a sudden large drop in level and often becomes undetectable. Therefore, a dropout is a special case of a gain hit (a decrease in signal level). (Bell Telephone Laboratory studies have shown that some dropouts are difficult to observe, because simultaneously with a signal level drop of 20 or 30 dB, the background noise may rise to a level near the original signal level.) The level of the received signal may return to its original value in a short time or remain undetectable indefinitely. Waveform (e) in figure 4-7 illustrates a received holding tone that includes interfering dropouts.

4-57. Since dropouts interrupt the information signal between two modems, all communication ceases during the dropout, and data can be lost. Furthermore, communication cannot immediately resume when the signal returns. The receiving modem must re-reference itself to the signal before successful data communication can resume, and more information can be lost. Most modems, however, can track the receive signal to a level as low as 12 dB below their nominal receiving power. Beyond 12 dB, the modem would then consider the information signal lost.

4-58. SIMULTANEOUS MEASUREMENT OF IMPULSE NOISE, HITS AND DROPOUTS

4-59. The relationship between each of the transient distrubances is summarized in table 4-1. As can be seen in the table, the most apparent way to distinguish impulse noise from hits and dropouts is the 4 mS maximum duration of the impulse noise. Phase hits can be distinguished from gain hits and dropouts because phase hits cause a change in phase. Dropouts have to be distinguished from gain hits by definition, since dropouts are a special case of gain hits. Table 4-2 summarizes the measurement definitions necessary for implementing a practical measuring instrument.

4-60. The information needed about each of these disturbances includes how often they occur. So the measuring instrument is required to totalize each of the disturbances over a specified time period. Earlier test sets were limited to a maximum count rate of approximately 7 counts per second by the "dead time" (approximately 150 mS) of the available electro-mechanical counters. Years of experience and Bell Telephone Laboratory studies have shown that limiting the maximum counting rate to 7 counts per second produces valid impulse noise data, hence the current Bell standard (7 counts per second maximum count rate).

4-61. All of these disturbing events can occur at any time, since they are caused by random sources. Bell Telephone Laboratory studies have also shown that impulse noise can occur in clusters with only a few milliseconds between each impulse noise spike. With electronic counters (as incorporated in TIMS), it is possible to remove the 7 counts per second limitation and allow the measuring device to count disturbances at a rate limited only by its ability to distinguish between the disturbances (approximately 30 counts per second with TIMS).

4-62. Since not all disturbances are of sufficient magnitude to cause data communication problems, it is necessary to be able to set thresholds that will discriminate against small disturbances. The thresholds in TIMS are adjustable so that measurements can be made at different Test Level Points; and also so that the test set can be made to be susceptible to certain disturbances depending on the effect those distrubances have on current data communications.

4-63. By sensing all four phenomena simultaneously, TIMS is able to identify coincident phenomena situations and reliably sort out and prevent from being counted the phenomena that occurred only as the result of another phenomena. This is shown in figure 4-8.

Table 4-1. Transient Phenomena Summary

DISTURBANCE	SIGNAL RELATED	CHANGE CHARACTERISTIC	DURATION
Impulse Noise	No	Level & Phase	< 0.1 mS to 4 mS
Phase Hit	Yes	Phase	< 0.1 mS to > hours
Gain Hit	Yes	Level	< 0.1 mS to > hours
Dropout	Yes	Level	≈1 mS to > hours

Table 4-2. Measurement Definitions

DISTURBANCE	SIGNAL RELATION	DURATION
Impulse Noise	Level change not related to signal.	Lasts less than 4 mS.
Phase Hit	Phase change to the signal.	Lasts greater than 4 mS.
Gain Hit	Level change to the signal.	Lasts greater than 4 mS.
Dropout	Decrease in signal level of 12 dB.	Lasts greater than 4 mS.

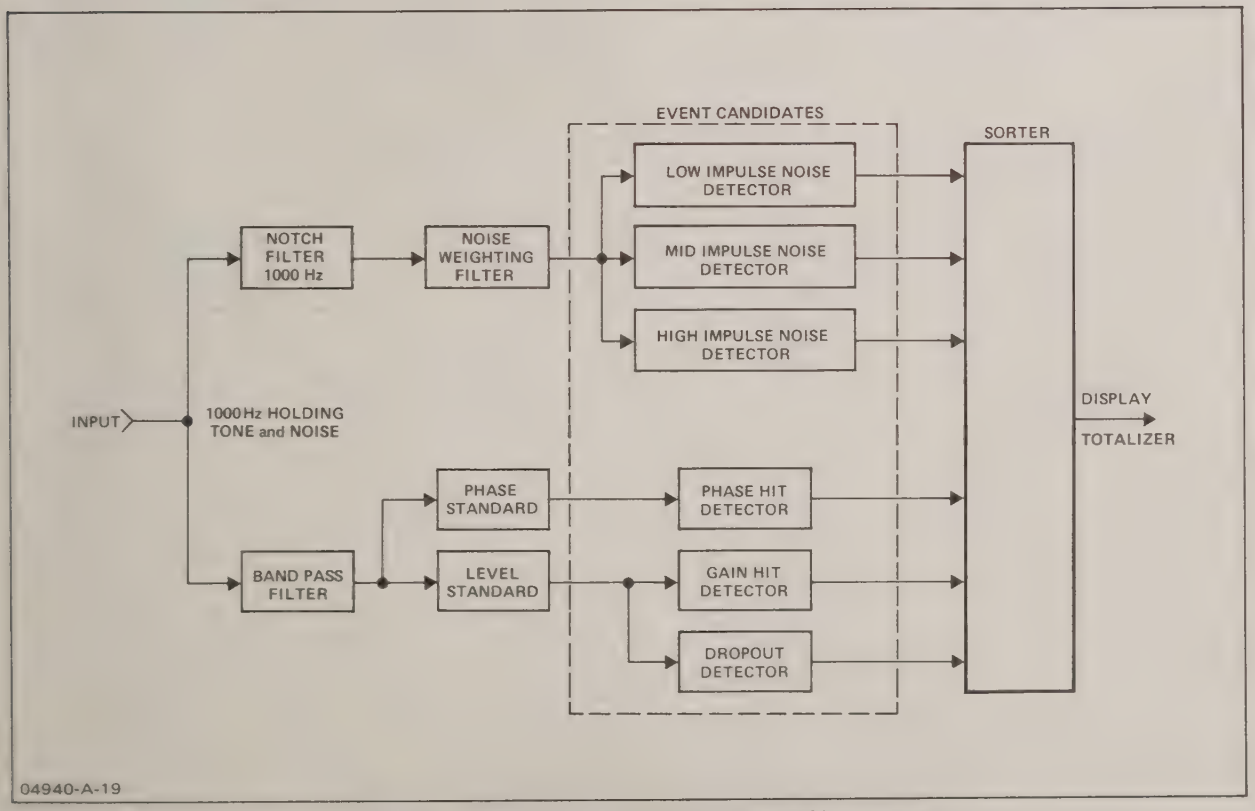


Figure 4-8. Impulse Noise, Hits and Dropouts Measurement

4-64. PHASE JITTER MEASUREMENT.

4-65. The phase jitter mode allows measurement of the peak-to-peak phase deviation on a voice channel. Phase jitter is the undesired component of a received signal which appears as phase (or frequency) modulation.

4-66. Phase jitter has an insignificant effect on voice transmission because the ear is relatively insensitive to phase information. However, phase jitter can seriously affect data transmission. Phase jitter is especially interfering to data communication systems that use phase modulation as the transmission scheme. If large phase variations occur, one data pulse may occupy the alloted time slot of another pulse (intersymbol interference), causing an error to occur. Figure 4-9 illustrates the effect of phase jitter on a reference holding tone.

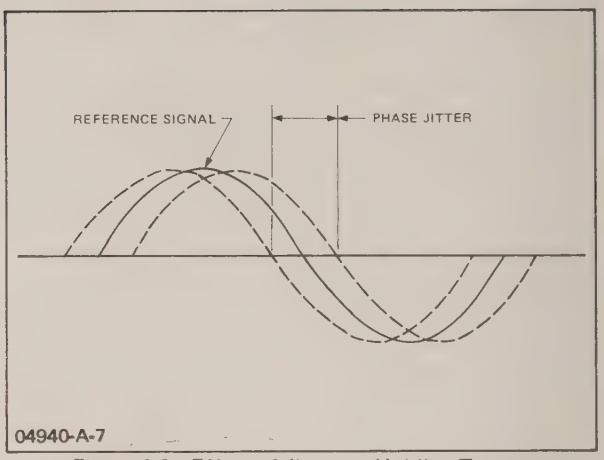


Figure 4-9. Effect of Jitter on Holding Tone

4-67. Various sources cause the instantaneous phase of a signal to jitter at rates normally less than 300 Hz. Phase jitter is typically caused by ripple in the dc power supply of the master oscillator of long haul carriers. Some phase jitter also occurs in short haul systems from incomplete filtering of image sidebands. The most commonly found frequency components of phase jitter are 20 Hz (ringing current), 60 Hz (commercial power), and the harmonics of these.

4-68. To measure phase jitter, a 1004 Hz holding tone is transmitted at data level. At the receiving end of the voice channel is the test set configured to measure phase jitter. Figure 4-10 illustrates the receiving TIMS functional configuration. The received signal passes through the 400-1550 Hz band-pass filter. This filter reduces the effective measurement bandwidth to approximately one-fourth the total channel width, centered on the test tone frequency.

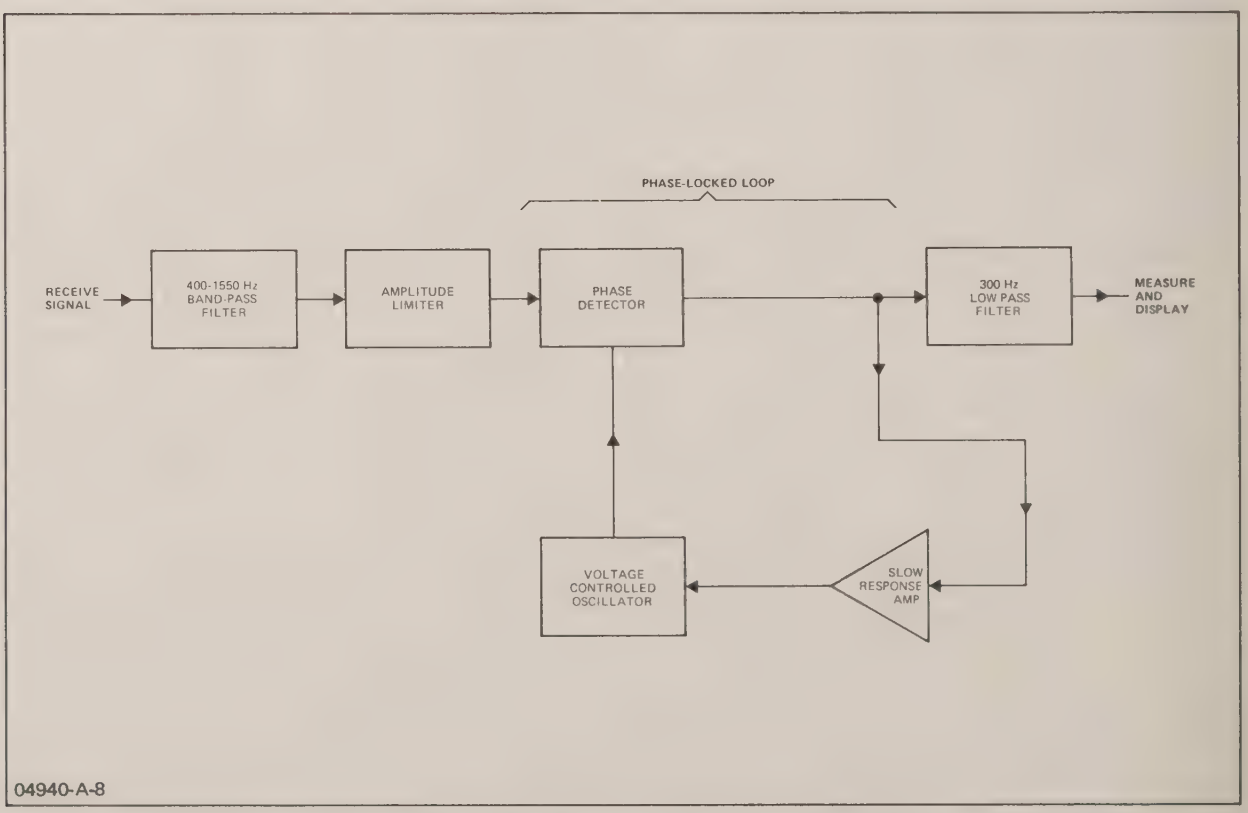


Figure 4-10. Phase Jitter Measurement

This reduces the effects of noise and other interference on the jitter measurement. The remaining received signal (test tone with both phase and amplitude variations) passes through the amplitude limiter to produce a constant amplitude signal. The phase detector compares the received signal (with phase jitter components) with the voltage controlled oscillator signal (jitter free reference). The oscillator is phase-locked to the long term average of the received signal.

4-69. Slow deviations in phase of less than a 20 Hz rate are followed by the phase-locked loop, made up of the phase detector, the slow response amplifier, and the voltage controlled oscillator. The amplifier will change the frequency of the voltage controlled oscillator. The voltage controlled oscillator then supplies the proper frequency (and phase) to the phase detector to result in a negligible phase difference between the received signal and the oscillator frequency.

4-70. The phase-locked loop will not follow fast phase changes which occur at a rate greater than 20 Hz. The slow response amplifier will not react fast enough to change the oscillator frequency to match the received frequency. Fast phase changes will cause an error signal to be generated by the phase detector.

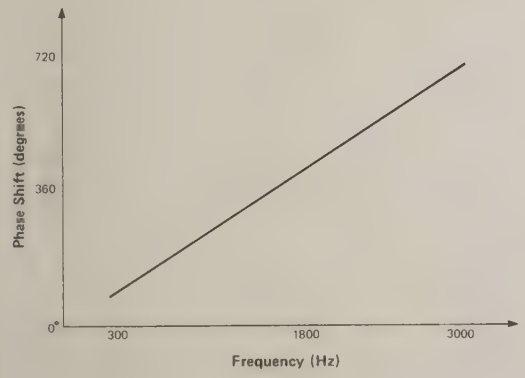
4-71. The error signal appearing after the 300 Hz low pass filter is limited in frequency between 20 Hz and 300 Hz. This pass band is utilized to include the phase jitter interference caused by 20 Hz ringing and 60 Hz power, plus their first several harmonics. Phase jitter components rarely occur above 300 Hz. However, jitter above 300 Hz is accompanied by large amounts of jitter below 300 Hz, which allows detection by the TIMS measuring arrangement.

4-72. ENVELOPE DELAY MEASUREMENT.

4-73. The envelope delay mode allows measurement of the linearity of the phase versus frequency of a voice channel.

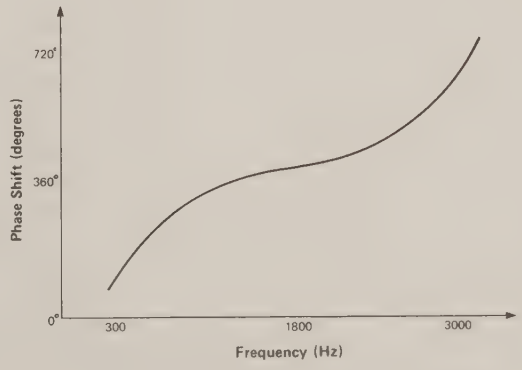
4-74. Phase information has an insignificant effect on voice transmission, because the ear is relatively insensitive to phase distortion. However, phase distortion can seriously affect data transmission. For example, with data transmitted at speeds greater than about 2400 bits per second, over a voice channel without proper delay compensation, and data bits tend to smear out in time and overlap each other; causing intersymbol interference which produces errors.

4-75. An ideal circuit which has a linear phase shift characteristic will produce a straight line slope (a linear relationship between a change in frequency and a corresponding change in phase) as shown in figure 4-11a. The practical circuit, however, is never ideal and will produce a nonlinear phase shift characteristic (phase distortion) as shown in figure 4-11b.



(a) Ideal Linear Phase Characteristic

04940-A-9



(b) Practical Nonlinear Phase Characteristic

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Figure 4-11. Phase versus Frequency Relationships

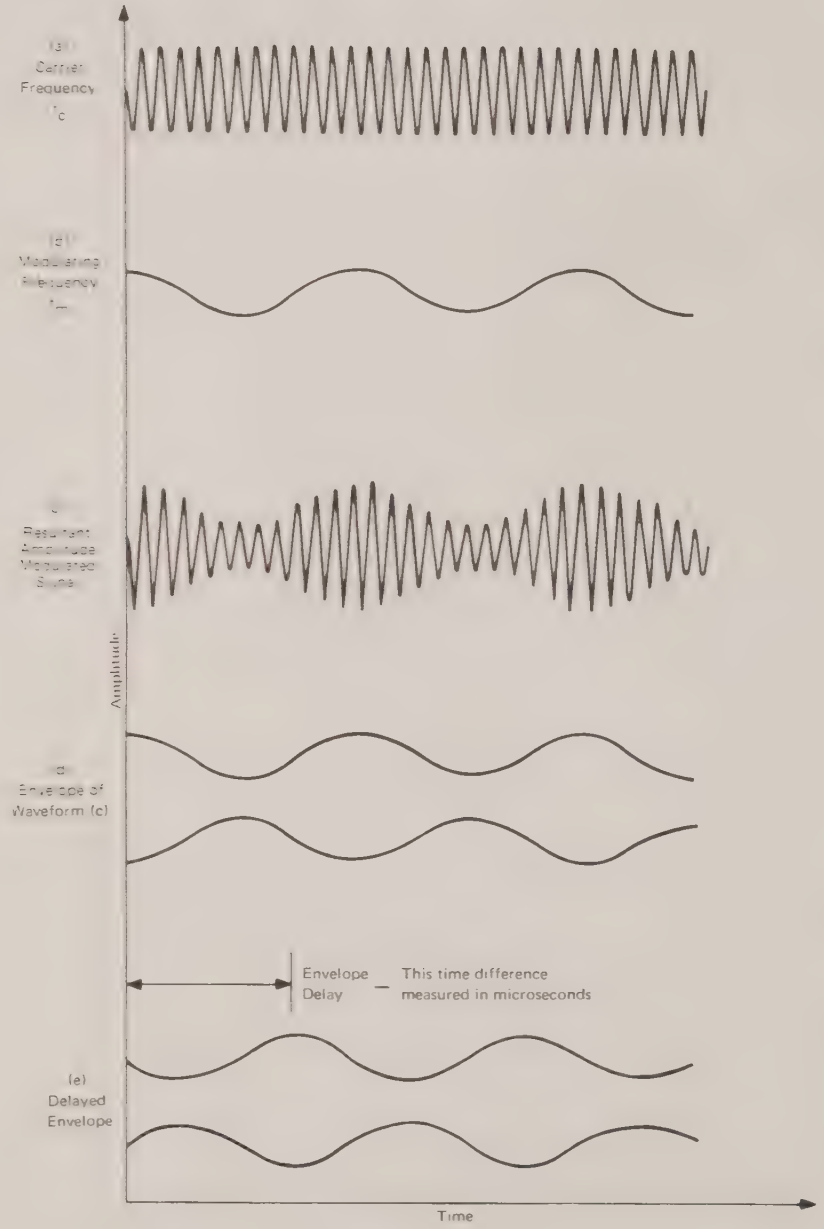


Figure 4-12. Envelope Delay Waveforms

4-76. Conventional measurement techniques make it difficult to measure the phase characteristic of a transmission system, since a phase reference is difficult to establish at the receiving end of the circuit. It is possible, however, to measure relative phase shift at the receiving end using the envelope delay measurement technique. This technique makes it possible to measure the envelope delay distortion of a voice channel, which provides a relative measure of the phase linearity (or non-linearity) of the circuit.

4-77. RELATING PHASE SHIFT TO ENVELOPE DELAY.

4-78. Amplitude modulating a low frequency sine wave (f_m) onto a carrier frequency (f_c) produces an amplitude modulated (AM) signal as shown by waveforms (a), (b), and (c) in figure 4-12. The envelope of the AM signal is the outline (or shape) of the peak excursions of the modulated signal as shown in waveform (d) of figure 4-12. The AM process produces a signal whose spectrum consists of the carrier frequency plus an upper sideband ($f_c + f_m$) and a lower sideband ($f_c - f_m$). Figure 4-13 illustrates this relationship. Since the upper sideband is of a higher frequency than the carrier, it undergoes a greater phase shift than the carrier; since the lower sideband is of a lower frequency, it undergoes less phase shift.

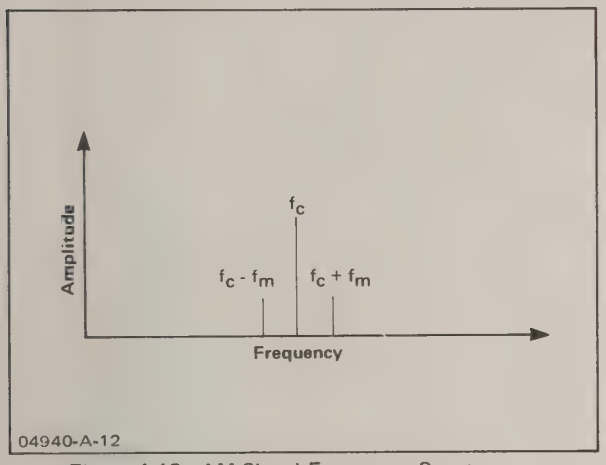


Figure 4-13. AM Signal Frequency Spectrum

4-79. If the AM signal is passed through a circuit having a phase shift characteristic which increases linearly with frequency (figure 4-11a), the envelope of the AM signal experiences a shift in time (or delay) as shown in waveforms (d) and (e) of figure 4-12. This occurs because the lower sideband experiences less phase shift than the carrier, while the upper sideband encounters more. The net result of these phase shifts is that the modulation envelope is shifted in phase (or delayed) when traversing a transmission medium.

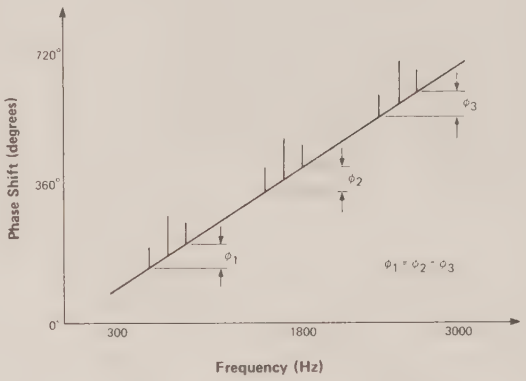
4-80. The amount of envelope delay is related to the difference in phase between the two sidebands. If the phase versus frequency characteristic of the transmission medium is linear, then any carrier frequency used (with a fixed modulation frequency) will produce a constant envelope delay value. Plots (a) and (b) in figure 4-14 illustrate this relationship. However, if the phase versus frequency characteristic is nonlinear, then different carrier frequencies will produce different envelope delay values. Plots (c) and (d) in figure 4-14 illustrate this relationship. When different values of envelope delay occur, the difference between delay values at two different carrier frequencies is termed "envelope delay distortion".

4-81. ENVELOPE DELAY MEASUREMENT TECHNIQUE.

4-82. To make this measurement, two TIMS are used in the configuration shown in figure 4-15. The TIMS normal test set transmits a test signal over the voice channel under test to the TIMS repeat test set. The repeat set responds by transmitting envelope delay information back to the normal set over the return reference voice channel. The normal set compares its received signal with its transmitted signal to determine envelope delay distortion values.

4-83. The normal set transmits an amplitude modulated test signal consisting of a variable frequency carrier (300 to 3904 Hz) and a fixed modulation frequency (83-1/3 Hz). The carrier frequency is varied over the band of interest, usually in 100 Hz steps. The test signal traverses the voice channel under test and is received by the repeat set. The receiver of the repeat set amplitude demodulates the incoming test signal to produce the AM envelope. Changing the carrier frequency as mentioned above will result in a change in the delay of the 83-1/3 Hz envelope at the repeat set, if envelope delay distortion exists. The envelope delay values received at the repeat set must now be transmitted back to the normal set for measurement. In addition, the envelope delay values received at the repeat set must be transmitted back to the normal set without the introduction of a changing envelope delay, as would be introduced by changing the return reference carrier frequency.

4-84. In the repeat set, the demodulated AM signal is used to amplitude modulate the fixed frequency carrier that is transmitted back to the normal set. The repeat set carrier oscillator remains fixed at one frequency during the envelope delay measurement. The carrier frequency is usually selected at midband (nominally 1800 Hz) because envelope delay characteristics are fairly constant and attenuation distortion characteristics are fairly flat. Since a constant return reference carrier frequency is used by the



(a) Linear Phase Characteristic with Superimposed AM Signal Components

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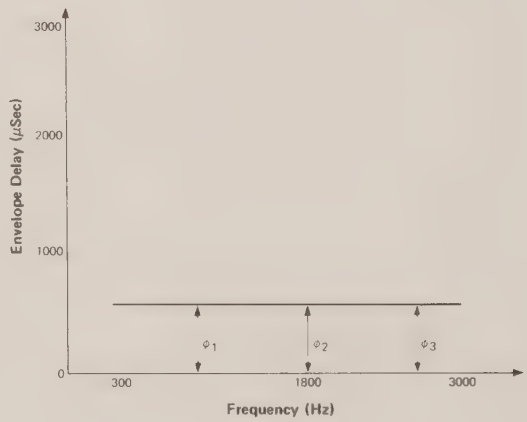

(b) Envelope Delay Characteristic of (a) above.

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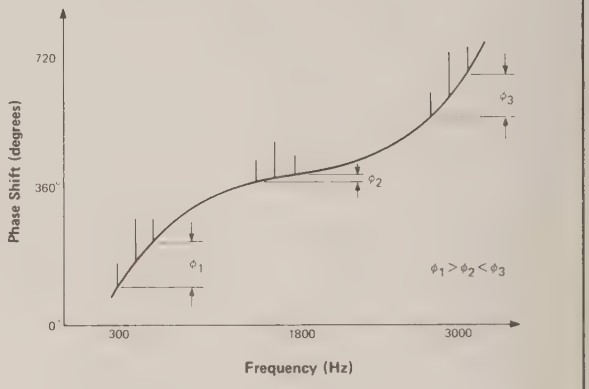

(c) Nonlinear Phase Characteristic with Superimposed AM Signal Components

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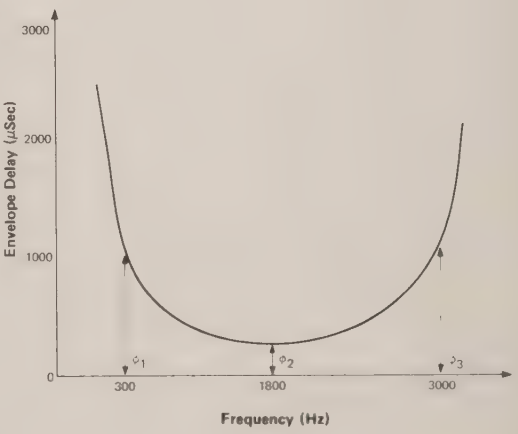

(d) Envelope Delay Characteristic of (c) above.

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NOTE: The symbol phi (ϕ) represents the difference in phase between the upper and lower sidebands of the AM signal superimposed on the phase characteristic plots.

Figure 4-14. Relating Phase Shift to Envelope Delay

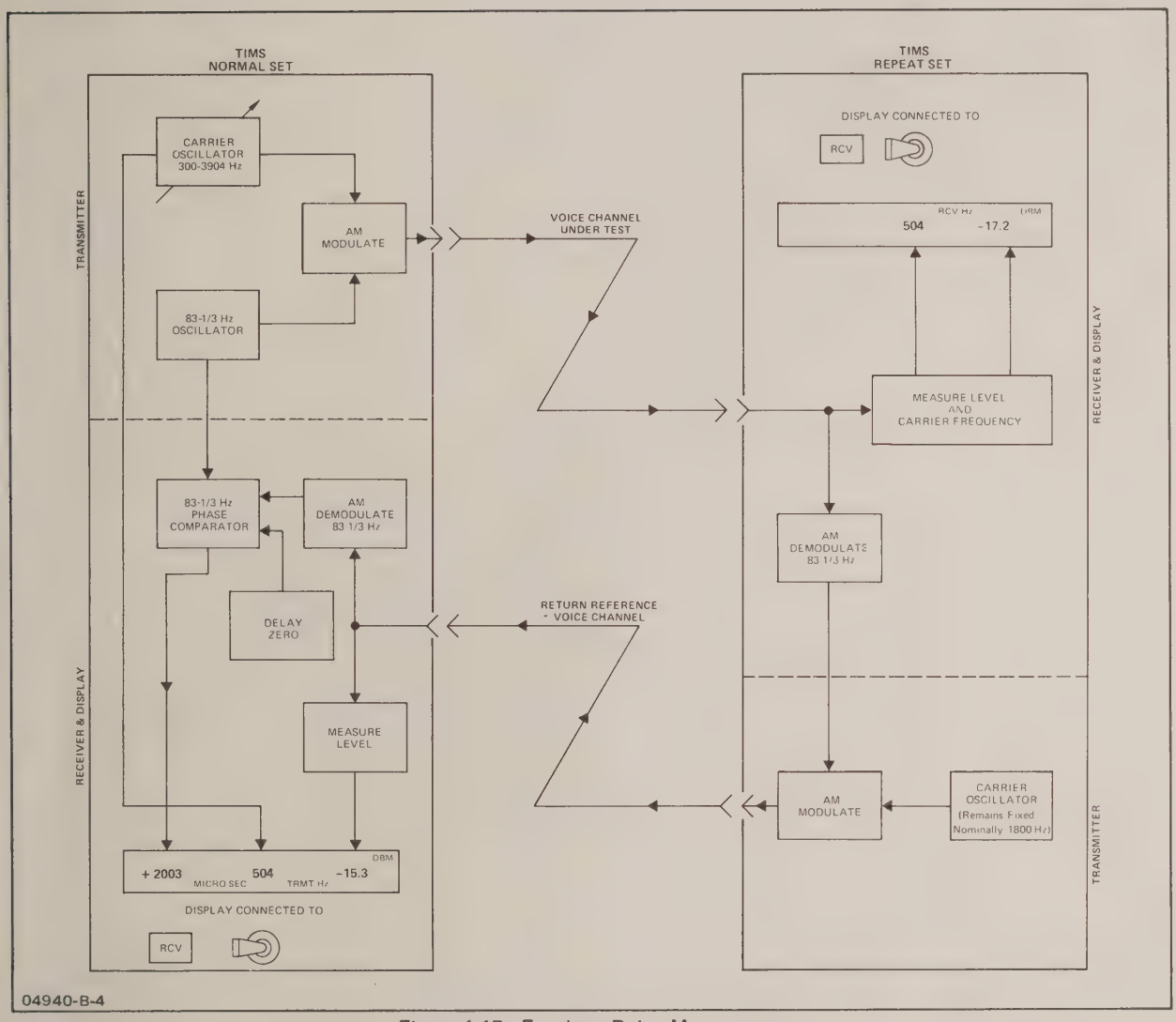


Figure 4-15. Envelope Delay Measurement

repeat set, there will be no envelope delay distortion encountered by the return reference signal (although there will be a fixed envelope delay). Therefore, the envelope delay value received at the normal set will represent the envelope delay value received at the repeat set, plus the constant envelope delay of the return reference channel.

4-85. The receiver of the normal set amplitude demodulates the incoming return reference signal. The phase of the incoming return reference envelope is then compared to the original 83-1/3 Hz oscillator signal to determine the difference in phase (envelope delay) between the two signals.

4-86. To measure the change in envelope delay from the normal set to the repeat set (with a change in carrier frequency), a delay zero control is used to "zero out" the envelope delay of the entire measurement loop. The delay zero control sets the phase difference (or envelope delay) between the 83-1/3 Hz oscillator and the demodulated return reference envelope to zero. All future envelope delay measurements on the channel will then be referenced to the carrier frequency of the normal set where the delay zero was set. By changing the normal set carrier frequency from the delay zero reference value, the only changing envelope delay (envelope delay distortion) occurring in the measurement loop is that incurred by the test signal traversing the voice channel under test.

4-87. The delay zero function is usually implemented at a normal set carrier frequency of around 1800 Hz. For some tests it is convenient to set an arbitrary zero and vary the test frequency while looking for the largest negative envelope delay value. By setting a new zero at this frequency of minimum delay, all other envelope delay measurements (on the channel under test) will have positive values.

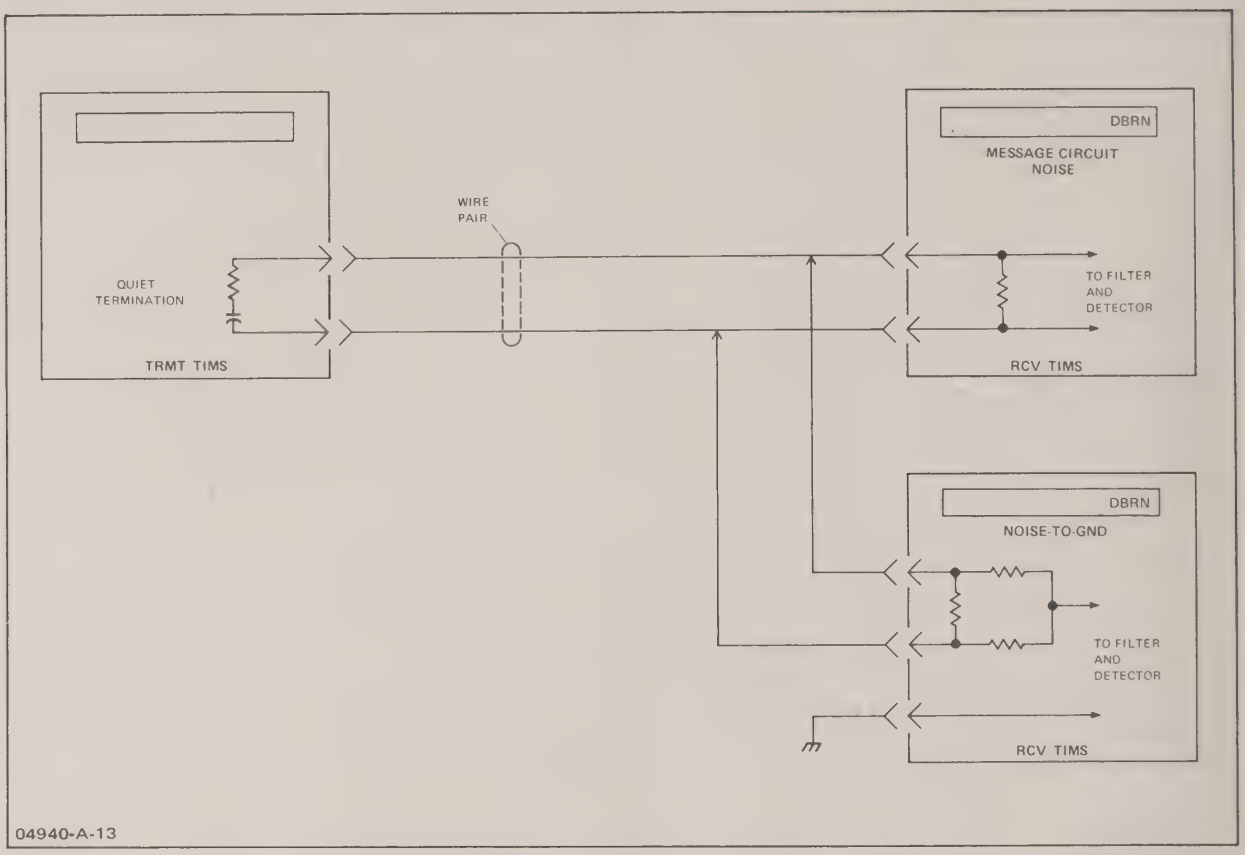


Figure 4-16. Noise-to-Ground Related to Message Circuit Noise

4-88. NOISE-TO-GROUND MEASUREMENT.

4-89. The noise-to-ground mode allows measurement of the longitudinal noise present on a voice channel, with reference to ground. The transmitting TIMS provides a quiet termination at one end of the voice channel, and the receiving TIMS provides a frequency weighted filter (C-message or 3 kHz flat) and detector at the other end. The basic measurement technique used for the noise-to-ground measurement is very similar to the message circuit noise measurement; the main difference lies in the use of a ground reference. Figure 4-16 illustrates this difference.

4-90. Noise-to-ground measurements are usually made for troubleshooting purposes; to measure the magnitude of longitudinal signals, which may indicate the susceptibility of a cable pair to electrical coupling from external sources. These measurements are also made to coordinate new installations with power companies, to minimize power line coupling.

4-91. The relative line balance of an end loop can be calculated by subtracting the measured noise-to-ground (N_g) value from the measured message circuit noise (N_m) value. This calculation is only valid if the measurements are made on a physical pair and it is assumed that the message circuit noise is caused by longitudinal noise converted to message circuit noise by line imbalance. It is recommended that both message circuit noise and noise-to-ground be measured with the 3 kHz flat weighted filter to include the effects of power line related noise.

4-92. NONLINEAR DISTORTION MEASUREMENT.

4-93. The nonlinear distortion mode allows measurement of the second and third order intermodulation distortion products of two test tone pairs transmitted over a voice channel.* The test tone pairs are selected to closely approximate the nonlinear distortion properties encountered by data signals; to minimize the effects of channel roll-off, phase jitter, frequency translation; and to avoid inaccurate readings on PCM carrier systems. Figure 4-17 illustrates the spectrum of the transmitted nonlinear distortion test signal.

*This non-linear distortion analyzer circuit is licensed under Hekimian Laboratories, Inc. U.S. Patent No. 3,862,380.

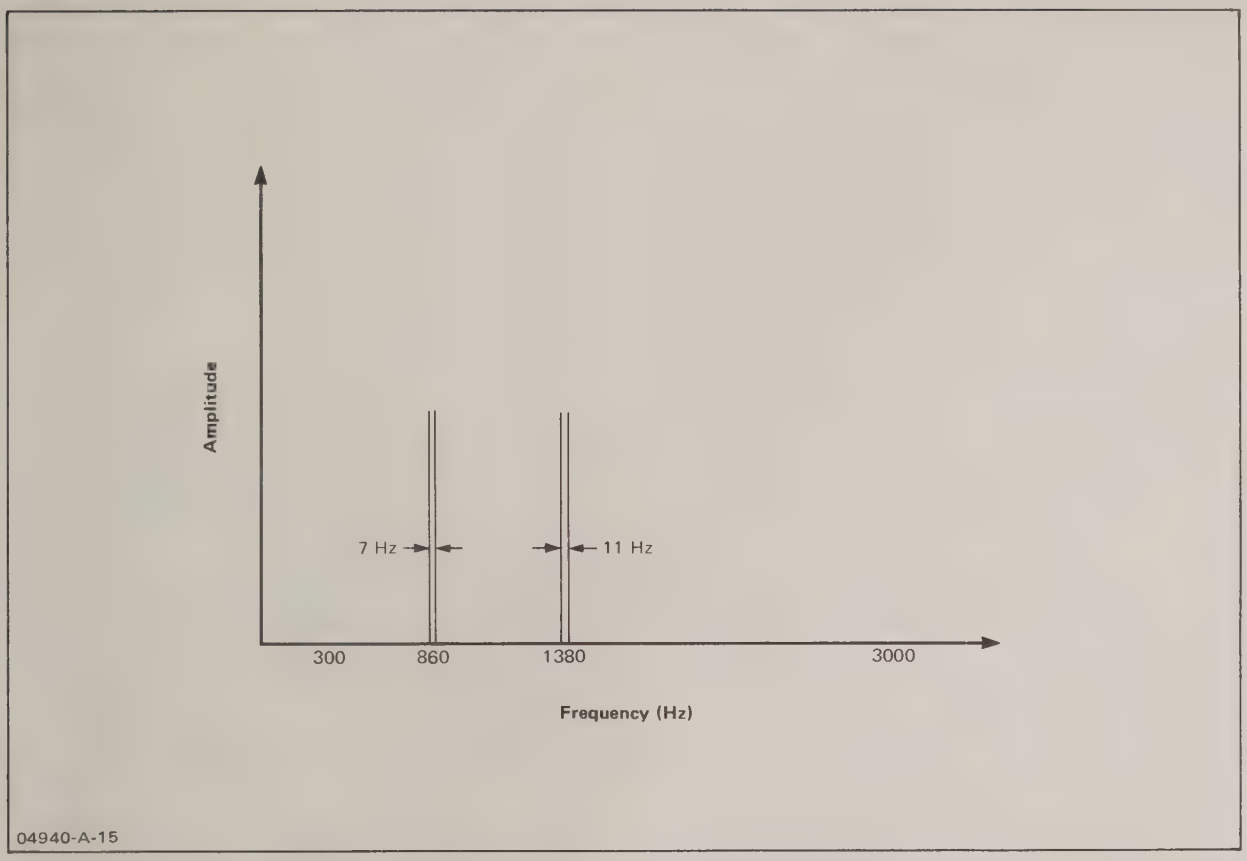


Figure 4-17. Nonlinear Distortion Transmit Signal Frequency Spectrum

4-94. Nonlinear distortion is the generation of new signal components not present in the original transmitted signal. This usually happens when a channel's loss is nonlinear with respect to input level. The main causes of nonlinear distortion are electronic devices such as modulators, demodulators, and amplifiers.

4-95. With a single frequency (f_1) applied to the input of a nonlinear device, the nonlinear distortion appears as harmonics of the input frequency, such as $2f_1$, $3f_1$, $4f_1$, etc. This type of distortion is termed "harmonic distortion". With a multiple frequency signal (f_1 and f_2) applied to the device input, the nonlinear distortion appears as harmonics of the individual input frequencies plus intermodulation products of the input frequencies, as listed in table 4-3. This type of distortion is termed "intermodulation distortion", and is the type measured by TIMS. Bell Telephone Laboratory studies have shown that it is valid to measure the power sum of the distortion products $f_1 + f_2$ and $f_2 - f_1$ as representative of the second order distortion, while $2f_2 - f_1$ may be measured as representative of the third order distortion; which is the technique utilized by TIMS.

Table 4-3. Harmonics and Intermodulation Products of a Multiple Frequency Signal (f_1 and f_2)

TYPE OF DISTORTION	OUTPUT DISTORTION THRU THE THIRD ORDER
Harmonics	$2f_1$, $3f_1$, $2f_2$, $3f_2$
Intermodulation Products	$f_1 + f_2$, $f_2 - f_1$, $2f_1 + f_2$, $2f_1 - f_2$, $2f_2 + f_1$, $2f_2 - f_1$

4-96. Intermodulation distortion and harmonic distortion measurement techniques will yield the same value for second and third order distortion in the simple case involving only one source of distortion. However, with a telephone channel there are normally multiple sources of distortion joined together by linear networks with delay distortion. This creates measurement problems in obtaining valid distortion values. Bell Telephone Laboratory studies have shown that the intermodulation distortion technique is less susceptible to these measurement problems.

4-97. The check signal provision is included in TIMS to permit correction of error caused by the presence of high background noise, an interfering tone, or T-carrier quantizing noise. When the NONLINEAR DISTORTION key is momentarily thrown to the CHECK SIGNAL position, the second tone pair shown in figure 4-17 (as centered at 1380 Hz) is supressed, and the lower tone pair is doubled in power. This allows the channel to be checked with a test signal of the same power. Without the two tone pairs being generated, the intermodulation process (as measured by TIMS) does not occur. The receiving TIMS looks for the second and third order products, but since these are not present, the measured received signals consist of noise. The second and third order products as measured with the two tone pairs may then be corrected accordingly to achieve accurate values.

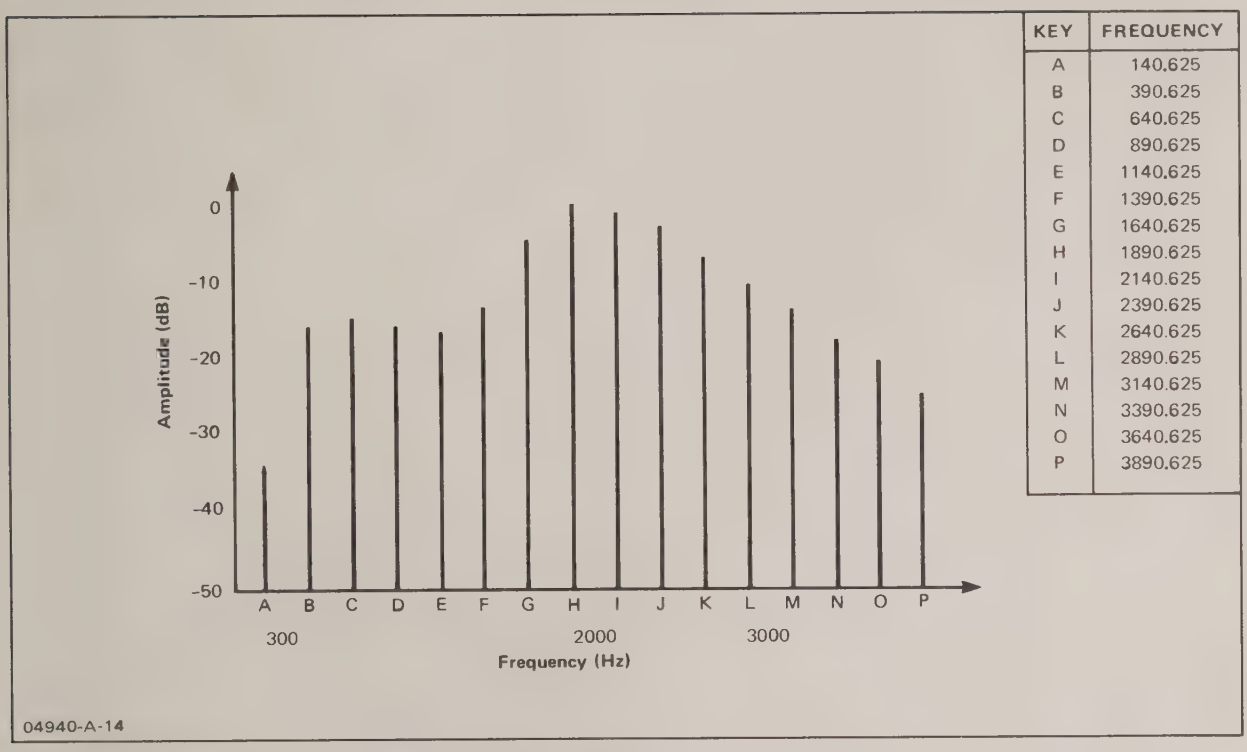
4-98. PEAK-TO-AVERAGE RATIO MEASUREMENT.

4-99. The peak-to-average ratio (P/AR) mode allows measurement of the channel dispersion (spreading in time of signal amplitude) due to transmission imperfections. As the P/AR signal traverses a dispersive medium, the peak-to-average ratio will deteriorate. Then by measuring the peak-to-average ratio at the receiving end, a simple measure of dispersion is obtained. P/AR is measured as the ratio of the peak to full-wave rectified average values of a specially processed test signal transmitted over a voice channel. The test signal has a peak-to-average ratio and a spectral content that approximates a data signal. Figure 4-18 illustrates the frequency spectrum of the transmitted P/AR test signal, and figure 4-19 illustrates the signal envelope.

4-100. The P/AR rating is a single number rating of the fidelity of a channel and is a weighted measure of the total attenuation, phase distortion, and noise. The P/AR rating is derived by comparing the P/AR of an ideal signal with the P/AR of the output signal of the system under test. The P/AR measurement is most sensitive to envelope delay distortion and is also affected by noise, bandwidth reduction, gain ripples, nonlinearities such as compression and clipping, and other impairments. The P/AR rating is an indication of the general transmission quality of the voice-band channel. If the P/AR signal were received entirely undistorted, the P/AR rating would be 100, while a circuit that causes a 10% reduction in the peak-to-average ratio has a P/AR rating of 80.

4-101. The P/AR measurement provides little information about the nature of the fault condition in any particular case. However, since P/AR is a figure of merit for the channel, it can be used as a benchmark for future reference. After other measurements are made and a channel is considered acceptable, the P/AR rating can be recorded for future reference. In case of a suspected trouble on the channel, P/AR may be measured first and be compared to the benchmark P/AR value. Deviations in excess of ±4 P/AR units from an initial P/AR value provides sufficient reason to suspect that some channel characteristic has changed significantly.

4-102. The P/AR rating can also be useful in trouble-shooting on the DDD network where a number of connections are to be surveyed and full data recorded on only the worst connections experienced. In private line circuits, P/AR can help to identify the worst transmission direction (near to far, or far to near) such that measurement of the parameters in the worst direction can be completed first, since it is more probable that any transmission impairment will be in that direction.



KEY	FREQUENCY
A	140.625
B	390.625
C	640.625
D	890.625
E	1140.625
F	1390.625
G	1640.625
H	1890.625
I	2140.625
J	2390.625
K	2640.625
L	2890.625
M	3140.625
N	3390.625
O	3640.625
P	3890.625

Figure 4-18. P/AR Transmit Signal Frequency Spectrum

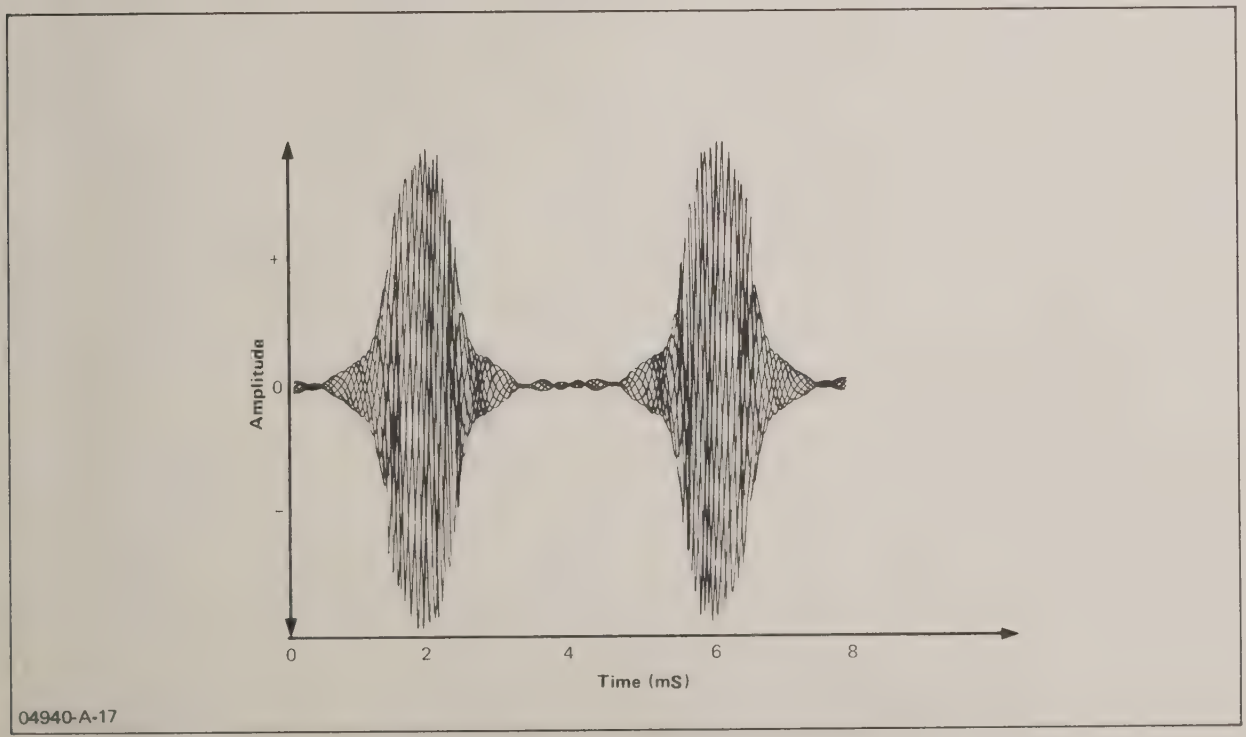


Figure 4-19. P/AR Transmit Signal Envelope

SALES OFFICES

Arranged alphabetically by country

1

ANGOLA
Telectra
Empresa Técnica de Equipamentos Eléctricos, S.A.R.L.
R. Barbosa Rodrigues, 41-1°DT.°
Caixa Postal, 6487
Luanda
Tel: 35515/6

ARGENTINA
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Santa Fe 2035, Martinez
6140 **Buenos Aires**
Tel: 792-1239, 798-6086
Telex: 122443 AR CIGY

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A-1205 **Wien**
Tel: 35-16-21
Telex: 135066

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Medical Only
Wael Pharmacy
P.O. Box 648
Bahrain
Tel: 54886, 56123
Telex: 8550 WAEL GJ

Al Hamidiya Trading and Contracting
P.O. Box 20074
Manama
Tel: 259978, 259958
Telex: 8895 KALDIA GJ

BANGLADESH
The General Electric Co. of Bangladesh Ltd.
Magnet House 72
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